The AMSAT Journal

Incorporating the AMSAT Newsletter

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Off the Pad

An Editorial

The Road to Phase IV

By Joe Kasser, G3ZCZ*

Twenty years ago, Project OSCAR had put Amateur Radio in space, not once but four times. Interest in the Amateur Radio space program was increasing rapidly and the Project OSCAR team was getting burned out doing "everything" themselves. Also, by this time the real authority and decision makers responsible for launch capabilities were to be found in Washington (DC) instead of on the West Coast. Therefore, the time was right for another organization located on the East Coast to pick up the ball and run.

On the 9th of January 1969, George Jacobs, W3ASK gave a talk to the COMSAT Amateur Radio Club, in Washington DC. During the talk, George suggested that the club help form an East Coast group to continue the space program begun by Project OSCAR. The idea took hold, and after a number of further meetings the Radio Amateur Satellite Corporation (AMSAT) was officially incorporated as a non-profit corporation in the District of Columbia on March 3rd 1969.

AMSAT's first project, in conjunction with Project OSCAR, was the launch AUSTRALIS-OSCAR 5, originally built by students at the University of Melbourne (Australia). AMSAT's project manager for that activity, and all subsequent satellites was Jan King (then K8VTR).

AMSAT-OSCAR 6 was AMSAT's first spacecraft. It became the world's first practical Amateur Radio communications satellite (the first Phase 2 spacecraft). AMSAT-OSCAR 6 was soon to be followed by AMSAT-OSCAR 7 which carried not one but two transponders and whose Mode B signal strength has to be experienced to be believed. AMSAT-OSCAR 7 was also an example of international cooperation. The Washington DC based group was no longer the only active group of Amateurs interested in flying equipment in space, component assemblies of AMSAT-OSCAR 7 came from Canada, Japan and the Federal Republic of Germany.

The AMSAT-OSCAR 6 and 7 spacecraft provided thousands of QSO's but had a number of operational problems, mainly due to the fact that they were in a less than optimum orbit. They were in the orbit that they were supposed to be, but that orbit was designed for the primary payload and not for Amateur Radio communications. For a start the orbit was low, passes lasted only 20 minutes or so and took place roughly 6 times a day. Being in a low orbit, the range (skip distance) was short and the DX potential was not good. WAC was just possible, but only to favored stations in a few select geographical locations. Stations in the southern hemisphere didn't have too many people to talk to. In spite of all that, they were used and many "firsts" were made. Hams began to pioneer new techniques for satellite applications once again. **If you were a member of AMSAT in the days prior to AMSAT-OSCAR-6 and 7, then you can chalk up a credit for each of the nearly 1000 lives saved by the SARSAT-COSPARS satellite search and rescue system.** The location technique which is now being used by that system was pioneered on AMSAT-OSCAR-6 and 7. **Your dues and contributions made those spacecraft possible.**

AMSAT's engineers dreamed on. They wanted to built a spacecraft that would be capable of serving all the world's Radio Amateurs most of the time for long periods of time, and do the job with a single spacecraft. Note that professional global satellite communications use a number of satellites in geosynchronous orbits, more or less equally spaced in orbit over the equator, and we needed to do the job with one spacecraft. The problem was studied and it was noted that the majority of Hams lived in the northern hemisphere. The majority of communications capability was required in an east-west direction rather than a north-south direction. It was also noted that the Soviet Union had a similar situation and had provided itself with Molniya satellite communications capability using an inclined orbit at about 60 degrees with a high apogee over the northern hemisphere. Careful calculations showed that this capability was achievable, and would provide the required service but the project would be much more sophisticated than AMSAT-OSCAR-7 and be much more expensive.

AMSAT and AMSAT-DL were in a quandary. While the communicators were glorying in being able to pass signals through the AMSAT-OSCAR 6 and 7 satellites in spite of needing a number of hands (one to tune the receiver, one for the transmitter, one to rotate the antenna in azimuth, one in elevation, one hand to hold the key or microphone and the last hand to write in the logbook (why do you think we got into computers in the first place?), they had the vision and knew what they wanted to build.

The ARRL, responsive to the current needs of their members, commissioned AMSAT to build a Phase 2 spacecraft as a replacement for AMSAT-OSCAR-6 (which was then suffering from battery problems and approaching the end of its useable lifetime), in return for a sizable donation toward the Phase 3 program. As such construction of the Phase 3A spacecraft was delayed for a year or so while AMSAT built and launched the AMSAT-OSCAR-8 spacecraft. Then after years of effort the Phase 3A spacecraft was lost on Friday May 23, 1980 due to a launch vehicle malfunction. It took two more tries, several years and lots of money until AMSAT was able to put a Phase 3 spacecraft into more or less the designed orbit. AMSAT-OSCAR-10 was almost there, in an elliptical orbit but at the wrong angle of inclination. Today AMSAT-OSCAR-13 and even AMSAT-OSCAR-10 with its idiosyncrasies provided us with reliable communications capability over intercontinental distances.

In the intervening years, other groups in other countries have put together the capability to build and even launch OSCARs. JAMSAT have contributed assemblies to several OSCARs and built and obtained a Japanese launch for FUJI-OSCAR-12. Russian Amateurs built Amateur space communications packages, 10 of which have been placed in orbit and AMSAT-UA is continuing the work. Project ARSENE in France are working on a spacecraft similar to the Phase 3 series. It will be built by 1992 and is to be a packet type of spacecraft with a store and forward system or a digipeater. The orbital parameters will be about 30,000 km at apogee and 10,000 km at perigee.

Amateurs at the University of Surrey in England have built and orbited the UoSAT-OSCAR-9 and 11 educational or

**Editor, see page 2 for address.*

scientific spacecraft and are building two more for launch as secondary payloads (togther with four MicroSats) on the SPOT-2 mission later this summer. With this diversity of capability also comes diversity of opinion regarding the future. Where do we go from here?

AMSAT-NA wants to pioneer the "Phase-4 Era". Phase 4 is a term first coined by G3ZCZ eight years ago in an editorial in the January/February 1981 issue of *Orbit Magazine*. Phase-4 spacecraft will be located in a geosynchronous orbit. They will appear to be nearly stationary in the sky, no more tracking. Ground stations will be able to use fixed antennas. AMSAT-NA would like to build and deploy two such spacecraft, one east of the US and one west giving 24 hours coverage to the majority of the world's Radio Amateurs. Now just as the cost of Phase 3 was a significant increase over the cost of the Phase 2 devices, Phase 4 will be significantly more expensive than Phase 3, and even though membership dues and contributions will help, they won't nearly be enough to cover the costs, and additional methods to fund the program must be employed. One such method is to capitalize on the knowledge we have gained over the years to build inexpensive high performance orbital platforms. Hence the MicroSat project. The first flock of MicroSats will demonstrate their capability. There is a market for small high-performance orbital platforms. The funds from the MicroSat project will be applied to the Phase 4 development much as the funds received from the ARRL for the AMSAT-OSCAR-8 spacecraft were applied to the Phase 3 project.

If we are going to deploy Phase 4 spacecraft we must plan their use. Within certain limits we can put almost any type of payload aboard. Apart from the linear transponder we can also add digital transponders for relaying packet radio messages, to perhaps supplement or even free up (unlikely but possible) some of the 20-Meter channels currently in use. We can put educational scientific modules on MicroSats. We can use the MicroSats to experiment with Phase 4 technology well before the first one is launched. The whole applications concept needs a lot of study. Even though its going to take several years before we get our first Phase 4 launch, there's a lot of work to be done between now and then.

The marriage between computers and Amateur Radio have given us smart rigs and packet radio. With packet you can exchange messages with other Radio Amateurs around the world. you can leave a message on your local vhf BBS for anyone in the world providing that you know the call sign of the person you are sending it to and the call sign of their local BBS. **Nobody ever said that Ham QSO's had to be restricted to real-time.** AMSAT members have been pioneering digital communications ever since they obtained the first ASCII STA (Special Temporary Authorization) from the FCC 10 years ago and W3IWI made the first Amateur ASCII transmission to G3ZCZ/W3 on 28 February 1979. They are still deeply involved in packet techniques. W3IWI runs what must be the world's busiest packet radio message switch. I claim the first non-real-time packet radio message between the USA and the Soviet Union, when a message left by G3ZCZ on N4QQ in Silver Spring, Md. last November was passed to UA3CR in Moscow via 4X1RU in Israel. Note that the message and reply took less time than conventional airmail postage would have taken. AMSAT members KB4ZJ and N4QQ with a modicum of help from G3ZCZ have set up N4QQ-1 as an east coast gateway passing messages via packet radio to 4X1RU and onwards to Europe and Asia, completing packet radio's round the world capability. AMSAT member Phil Karn, KA9Q is pioneering TCP/IP in Amateur Radio. AMSAT has strong connections with the Tuscon Amateur Packet Radio (TAPR) Association.

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The First Flock of MicroSats

By Tom Clark, W3IWI
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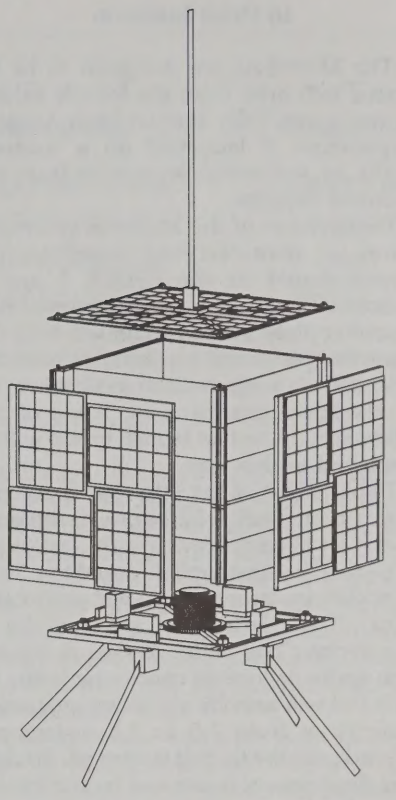
Jan King, W3GEY
Bob McGwier, N4HY
With assistance from the AMSAT-NA MicroSat Team *



Introduction

The new AMSAT-NA satellite concept is known as "MicroSat." A MicroSat is a cube with a mass of 8.5 Kg, measuring only 23 cm (9 inches) on each side excluding antennas. Being small, MicroSats can fit in hitherto unused space in a rocket payload bay. Don't judge their performance by their size because as you will see when you read on, **these satellites are the most sophisticated yet built for the Amateur Radio Satellite Service.**

The MicroSats are designed for use in a variety of low Earth orbits but will be most effective if placed into a sun synchronous orbit similar to the earlier Phase-II, AMSAT-OSCAR 6, 7 and 8 satellites. This article describes the feasibility, technologies, costs, and schedule associated with the first four spacecraft to be launched as part of the MicroSat project.

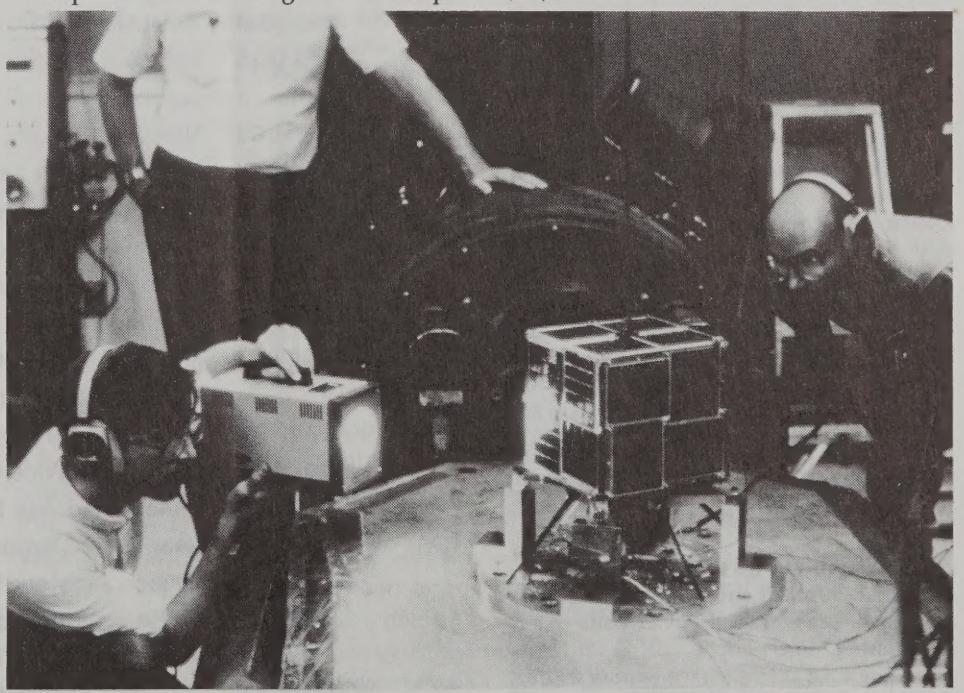
In the past, given one launch vehicle, AMSAT has built a single customized spacecraft or orbital platform with a number of payloads. AMSAT-OSCAR's 7 and 8 both contained two transponder payloads. The Phase-III spacecraft also contained a number of payloads. The MicroSats however are different in that they are standard spaceframe and equipment busses, unlike previous OSCARs which were each special purpose designed-from-scratch efforts. The MicroSat concept is a "minimum equipment bus." This bus contains transmitter, receiver, computer, and power system. These are the supporting parts of a spacecraft that any spacecraft builder would have to build, so we are standardizing them onto a single bus concept with extra space for any payloads. The software in the Onboard Computer (OBC) is treated in the same way; there is a standard compliment (operating system and certain operational applications) beyond which the owner/operator/user is free to do as he wishes.

Each satellite is expected to have a long service life. Its lifetime will probably be limited by radiation damage to the large RAM array. The batteries are 6 Ah GE aviation NiCads, the same type as those which have functioned flawlessly on UoSAT for over five years.

A bunch of four MicroSats will be launched together with two UoSAT-OSCAR spacecraft as secondary payloads on the SPOT-2 mission by an ARIANE-40 launch vehicle. This launch is currently scheduled for late 1989. The orbit for SPOT-2 is sun synchronous at a nominal altitude of 822 km. The planned apogee is 835 km, the perigee 817 km and the inclination 98.7 degrees. The MicroSats pass in optimal range of ground stations at approximately 10:30 a.m. and 10:30 p.m. local time daily. Although the four satellites will be in roughly the same orbit, there will be slight differences in the orbital parameters due to variations in deployment speed and direction from the launcher upper stage. This is exactly the same situation as that of the Russian Amateur Radio Satellites (Sputniks) RS-3, RS-4, RS-5, RS-6, RS-7, and RS- 8 which were deployed from the same launcher early in 1981. All six of them were in the same polar orbit and were within range of any one ground station at about the same time of day each day. Their relative positions throughout the orbit at any particular time changed from day to day and produced a good spread of operating opportunities.

The MicroSats are expected to be easy to access. The downlink signals should be quite loud, comparable to the signals from the Space Shuttle SAREX. You should be able to use omnidirectional antennas to copy signals from them.

The MicroSat spacecraft is a new satellite concept and must undergo the development engineering associated with such a project. In a business environment, this non-recurring engineering is a major portion of the cost of the first programs to use the new satellite. In this case, however, volunteers are providing much of the non-recurring engineering; the work can be shared over all four MicroSats and the six organizations participating in the MicroSat activity, namely AMSAT-NA, TAPR, AMSAT-LU, BRAMSAT, Weber State College, and the ARRL. The total materials cost for a MicroSat is approximately $65,000.



Chuck Stout and Jeff Zerr (with strobe) observe qualification of the MicroSat spacecraft structure at Utah State University in Logan, Utah. (Photo by Jan King, W3GEY)

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In Orbit Insertion

The MicroSats are designed to be inserted into orbit from the launch vehicle in two ways. They can use Man-Assisted Separation, if launched on a manned flight, or Automatic Separation from unmanned vehicles.

Deployment of the MicroSat spacecraft from a man-carrying satellite (as demonstrated in the ISKRA 1 and 2 spacecraft) will be by means of a modified launcher plate. An astronaut will hold the launcher plate and manually release the MicroSat via a release latch mechanism, into the space environment. None of the MicroSats in the first launch group will be deployed in this way.

Deployment of the MicroSat spacecraft from un-manned vehicles uses techniques that have been proven over the last twenty years. The spacecraft is locked to a launcher plate by means of a tie-bolt and locator pins. The tie-bolt is severed by a pyrotechnic bolt cutter device. A separation spring is located concentric to the tie bolt and will provide a positive separation velocity of from 1.0 to 1.5 meters per second once the tie-bolt is severed. Straight line deployment is assured by the locator pins. A separation switch on the spacecraft side of the interface will enable the satellite electronics with the exception of the transmitter before the separation takes place. A similar switch on the launcher side will indicate satellite separation via the launch vehicle telemetry system. The latter switch gives the launch vehicle team positive proof that the MicroSat was deployed.

MicroSat Hardware

A MicroSat spacecraft is composed of five aluminum frames (or modules) formed into a composite stack held together with stainless steel tie bolts. This stack, an approximately cubical structure, is referred to as the "frame stack assembly." Dimensions of the stack are 230 x 230 x 213 mm (9 x 9 x 8-3/8 inches). Each of the five frames of the stack assembly contain electronic sub-assemblies such as receiver, transmitter, computer, power supply and any special application modules. The modules are numbered 01 through 05 starting from the baseplate of the spacecraft.

The side panels are manufactured from solid aluminum 4.8 mm (3/16 inch) thick to assure that the solar cells mounted on the bonded aluminum honeycomb skin are not damaged due to buckling of the side panels.

Solar Arrays

The solar arrays on the satellite will consist of 20 identical sub-panels referred to as "clips" providing about 22 volts when illuminated. Each clip contains 20 high-efficiency solar cells each measuring 20 mm x 20 mm (0.79 inch x 0.79 inch) arranged in a 4 x 5 cell pattern. The power produced by the satellite solar panels will be in excess of 6.0 Watts for the worst case sun synchronous orbit when averaged over one orbit and can peak to as much as 15.7 Watts.

The solar cells achieve their 15%+ efficiency by incorporating a back-surface reflective coating. Photons that leak through without making a photoelectron have a second chance after they are reflected. The use of high-efficiency solar cells makes the MicroSat concept workable and we hope to use even higher efficiency GaAs technology in the future.

Five of the six surfaces of the MicroSat cube contain four clips each. The –Z sur-

GLOSSARY

AART	Addressable Asynchronous Receiver Transmitter
AMSAT	The Radio Amateur Satellite Corporation
AMSAT-LU	AMSAT of Argentina
AMSAT-NA	AMSAT of North America (U. S. and Canada)
ARRL	The American Radio Relay League
BCR	Battery Charge Regulator
BPSK	Binary Phase Shift Keying
BRAMSAT	AMSAT of Brazil
Canted Turnstile	Turnstile antenna where the elements do not all lie in the same plane but are symmetrically bent out of it
CAST	Center for AeroSpace Technology, Weber State College, Ogden, Utah.
DOVE	Digital Orbiting Voice Encoder on BRAMSAT's MicroSat
DSB	Double Sideband
EDAC	Error Detection And Correction
FM	Frequency Modulation
FSK	Frequency Shift Keying
HDLC	High-level Data Link Control procedures
IF	Intermediate Frequency
ITU	International Telecommunications Union
LEO	Low Earth Orbit, generally, circular orbits up to 2000 km above the surface
LUSAT	AMSAT-LU MicroSat, an orbiting mailbox
MicroSat	New AMSAT-NA satellite bus concept
MS-DOS	Microsoft© Disk Operating System for personal computers
NiCd	Nickel-Cadmium, a battery cell type
NRZ-I	Non Return to Zero — change on one (Inverted)
NRZ-L	Non Return to Zero — Level (digital data)
NTSC	National Television Standards Committee
OBC	Onboard Computer
OSCAR	Orbiting Satellite Carrying Amateur Radio
PACSAT	Packet Radio OSCAR of AMSAT-NA, specializing in electronic mailbox services
PC	Personal Computer
Quadron	Quadron Service Corporation, Santa Barbara, CA.
RAM	Random Access Memory, generally read/write
ROM	Read Only Memory
TAPR	Tucson Amateur Packet Radio Association
TBA	To Be Announced
TVT	Telemetry Voice Transmitter Module
WEBERSAT	MicroSat of CAST at Weber State College, Ogden, Utah

face (bottom) will contain four 10-cell "half clips." The cells are rated to operate at an efficiency of 15.5% at a temperature of 20 degrees C and with higher efficiencies at lower temperatures. Plans are to operate the spacecraft at slightly lower temperatures so as to further increase solar cell efficiency and improve battery lifetime. At temperatures of -5 to +5 degrees C, each solar cell clip will produce at least 1.60 Watts. The side panels of the spacecraft (+X, −X, +Y, and −Y) will each contain four clips, two series pairs wired in parallel. Then the top panel (+Z) for DOVE, LUSAT, and PACSAT will contain four clips.

MicroSat Thermal Characteristics

The thermal (heat transfer) characteristics of the MicroSats are designed specifically for low earth orbit (LEO) operation. Spacecraft coatings are designed to minimize heat inputs from the sun, Earth and Earth reflection radiations. The objective is to keep the spacecraft temperatures low (in the −5 C to +5 C range) in order to promote as high an efficiency from the solar cells as is possible and extend the life of the Nickel-Cadmium storage cell batteries.

Spacecraft Antennas

There are two sets of antennas on each satellite; one for transmit, and another for receive. For LUSAT, PACSAT, and WEBERSAT, the 70 cm (437 MHz) transmit antennas are a set of four radiating elements mounted on the −Z surface (the face nearest the launcher while attached). These form a canted turnstile and when properly fed produce a circularly polarized signal along the Z axis. The antenna elements are made of flexible, springy, semi-cylindrical metal approximately 1.0 cm in width, similar to ordinary tape-measure blade material. This arrangement will assure that no nulls are produced by the antenna, even for users with linearly polarized antennas.

The DOVE uses a two-meter (145 MHz) canted turnstile made of the same material and mounted in the same way, producing similar performance.

For LUSAT, PACSAT, and WEBERSAT, the two-meter (145 MHz) receive antenna is a whip made of blade material mounted on the +Z surface of the spacecraft. This antenna will be a little shorter than a quarter wavelength long, due to launch vehicle constraints. Performance is not expected to suffer from using a non-resonant antenna since it is anticipated that the majority of users will transmit too much power anyway. The antenna has a linear polarization pattern. It is anticipated that transmitted uplink signals will be circularly polarized, making the link less sensitive to spacecraft orientation, but incurring a 3 dB penalty over the most favorable matched-polarization case.

On all the multiband satellites, we are still trying to combine the S, L, and 2-Meter band antennas into one antenna, based upon the discone design.

Spacecraft Attitude Control

The attitude of the satellites will be controlled by means of a passive magnetic technique. The spacecraft frame will contain four small permanent magnets aligned parallel with their north poles. LUSAT and PACSAT contain opposite polarity magnets, so that one will be optimized for the southern and the other for the northern hemisphere. The magnets will cause the satellite Z axis to rotate twice per orbit as the magnets "track" local geomagnetic field lines.

In order to eliminate thermal gradients that would otherwise build up across the spacecraft, particularly in the X-Y plane, the satellite will be made to rotate about the "stabilized" Z axis by four solar torquing vanes and several hysteresis damping rods. The four blade elements forming the turnstile antenna will each be painted white on one side and black on the other. A photon absorbed by the black side imparts one unit of momentum, while one that is reflected imparts two units.

The differential transfer of linear momentum of photons colliding with the white surfaces and the black surfaces will cause a net rotation about the Z axis. The rate of rotation will increase until equilibrium occurs between this torque and hysteresis damping caused by a series of small steel rods oriented parallel with the X axis. Energy damping occurs as the lossy iron rods cut the earth's magnetic flux lines which are parallel to the spacecraft Z axis as discussed above. The receive whip is painted black on both sides and does not apply appreciable torque to the spacecraft mass.

This technique was used very successfully on both the AMSAT-OSCAR 7 and AMSAT-OSCAR 8 spacecraft missions. The MicroSats are expected to rotate and complete one revolution once every one to four minutes.

Standard Spacecraft Bus

An innovative cost-reduction feature of the MicroSat design is the interconnection scheme. Instead of an elaborate handmade wiring harness connecting signals every which way (construction time for AMSAT-OSCAR 13: two months), the wiring in the MicroSat consists mainly of a ribbon cable running between the modules (construction time for a MicroSat: one hour). The modules also communicate with the OBC serially over a 6-inch-long Local Area Network (LAN) to cut down the number of wires in the bus.

Each module in each MicroSat, except the flight computer itself, will be attached to an AART (Addressable Asynchronous Receiver/Transmitter) board which is based on the Motorola MC14469 AART chip. This board provides a simple, standardized OBC-to-module interface for command (both discrete digital and analog multiplexer) and data. Wires on the bus carry +5, +8.5, and +10 volt DC-module power, an analog pair from the modules to the Analog to Digital Converter (ADC), various discrete control lines and mission specific signals. The AART data uses ordinary ASCII communications at 4800 bps. over the spacecraft LAN.

The AART provides up to 24 bits of command in increments of 8 bits. If a module does not need all the bits, the AART board has some IC's omitted. It also contains a 4-way conditioned thermistor multiplexer, and has 6 analog sensing points. It can be expanded with off-board multiplexer chips to a total of 20 analog channels plus 4 ther-

MicroSat Naming Conventions.

Spacecraft	Before Launch	After Launch	Organization
1	MicroSat-A	PACSAT-OSCAR-14	AMSAT-NA
2	MicroSat-B	DOVE-OSCAR-15	BRAMSAT
3	MicroSat-C	NUSAT-OSCAR-16	CAST
4	MicroSat-D	LUSAT-OSCAR-17	AMSAT-LU

Each before-launch designator will be replaced with the proposed appropriate OSCAR number upon successful deployment in orbit.

Further opportunities to launch small satellites may be afforded by *Pegasus*, a commercial rocket plane being developed by American Technologies. *Pegasus* is a solid-fuel rocket with a small wing, which can be dropped from a B-52, like the X-15 experimental rocket plane. Since the solid-fuel rocket has no throttle, the main way to control the final orbit is by adding ballast to the payload. The *Pegasus* has been configured so that small satellites can be used for this ballast. This may provide a stream of inexpensive launch opportunities for MicroSats

mistors without major surgery.

The spacecraft has a distributed analog multiplexer. The OBC can tell one module to place a properly conditioned telemetry voltage onto the analog wires. At this time all other modules "float" themselves from the analog wires.

Power Module

All MicroSats contain a power module which is slightly larger than the other modules so as to accommodate the battery cells. The power module will down-convert the power generated by the solar panels (the voltage of the arrays is 22 V) to the main battery bus voltage of 10 V. The module will contain two regulated supplies operating at 8.5 V and 5.0 V. These voltages are needed for all digital equipment and various analog circuitry operating in other satellite modules.

The module will also perform battery charge regulation, correcting for array and battery cell temperatures. The current from the arrays will be reduced when the battery is fully charged by adjusting the solar cell operating point. This is accomplished by increasing the array voltage away from the optimum operating point. This technique has been used on all AMSAT series spacecraft since AMSAT-OSCAR-7 and has been shown to be a very effective means of preventing battery overcharge.

The power module will contain eight 6 Amp-hour NiCd battery cells manufactured by GE/Gates. These cells will assure adequate capacity to operate the satellite during eclipse periods. The cells will be carefully matched for charge and discharge characteristics to assure maximum reliability and lifetime. The battery main bus voltage will be as high as 11.7 V when the battery is fully charged at ambient temperature and will be as low as 9.2 V at the maximum safe discharge level, 70% discharge. Similar batteries have functioned flawlessly on UoSAT for over five years.

The module is heavily instrumented with telemetry sensors. A sensor based on a saturated toroidal core is used to measure current without dissipating much power.

The On-Board Computer (OBC)

The On-Board Computer (OBC) is a low-power general purpose microcomputer based on an NEC V40 processor. It contains a 2k boot ROM, 256 kilobytes error-detecting-and-correcting (EDAC) program RAM, and 8 Megabytes of static RAM. The computer consumes approximately 1.5 Watts peak power and our belief is that the power consumption will average 0.5 Watts because the NEC V40 has a WAIT instruction and at this time we are not banging the EDAC memory until an interrupt occurs.

The OBC supports three primary areas of memory. A 2k byte ROM boot loader is non-volatile and provides a means of safely restarting the computer from a hard reset. For executable image storage, 256k bytes of RAM are implemented with Error Detection And Correction (EDAC) hardware employing twelve bits per byte, eight data bits and four check bits. User messages, telemetry mass storage, voice, picture, or other data are stored in a nominal two megabytes of RAM which is accessed in half megabyte switched memory banks and which may be individually powered down in order to conserve spacecraft power when not in use. Up to eight additional megabytes of RAM may be accessed as a serial-interface mass storage medium.

The OBC is responsible for ensuring that all spacecraft functions are properly carried out. The OBC is used to run the PACSAT flying mailbox. It is used to make DOVE talk. **Some sages have said that these satellites are primarily a PC clone in space!**

The software in the satellite is constantly collecting data from many sensors throughout all the modules of the satellite. This telemetry data is transmitted (at low power) on the downlink whenever the downlink is not otherwise occupied. It is also accumulated into files, which are made available to users as downloadable files. In the case of the Weber satellite, some of the CCD pictures will also be made available for downloading.

A single 8 bit analog to digital converter (ADC) in the computer measures voltages on a pair of bus lines reserved for analog measurements. The measurement range is linear 0-2.55V for counts corresponding to 0-255. Each count represents 10 mV. This ADC in addition to distributed multiplexers located in the other modules provides the means for the OBC to monitor operating parameters throughout the spacecraft for telemetry and operational purposes.

The watchdog timer guards against problems which could cause the spacecraft to "lock up." It resets the OBC if the onboard software does not toggle a specific line approximately each half second. This starts the ROM-based bootloader. In this mode, the transmitter is only switched on periodically, sending a couple of minutes of telemetry at 0.5 Watts. The onboard software can then be reloaded.

Onboard programs are managed by the Quadron Multi-tasking operating system which looks similar to MS-DOS to each of the running applications. This approach is used in order to allow ground based software development on existing PCs.

Since the processor in MicroSat is a V40 based system, software development can rely heavily on standard IBM PCs. MicroSat software is written in assembler and Microsoft C, linked with Microsoft LINK. Executable images are uploaded to the flight computer using the transparent mode of the AX.25 protocol or an equivalent, error free, binary transmission protocol.

Receiver Modules

LUSAT, PACSAT, and WEBERSAT all contain high-performance receivers the design of which makes maximum use of low-cost commercial components, such as a Motorola receiver chip designed for telephones and inexpensive Toko coils from Digikey. Each of the receivers operates on a single channel in the Amateur two-meter satellite band (145.8 - 146.0 MHz).

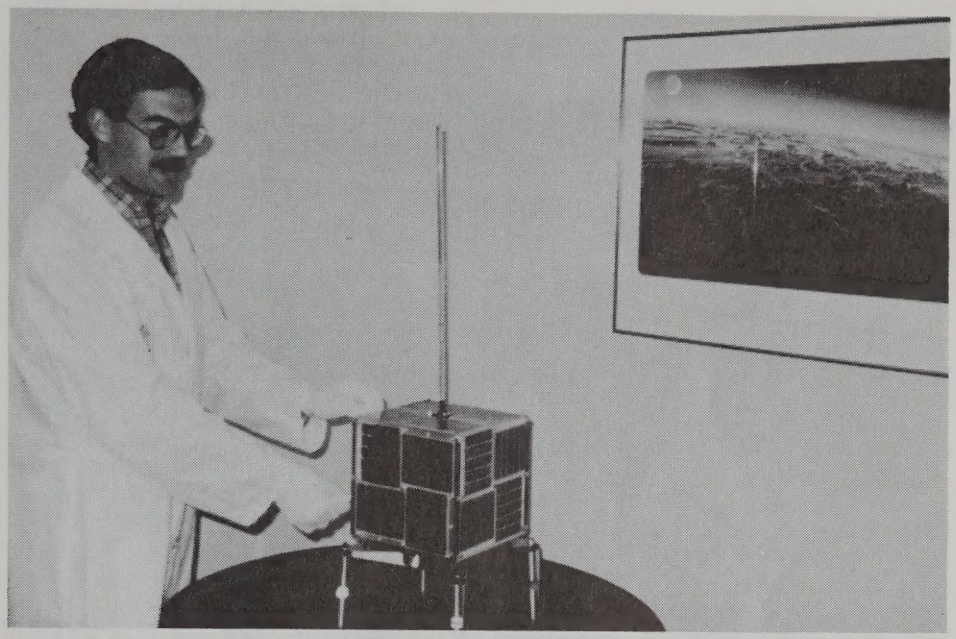
The 2-meter front-end preamplifier uses a robust (MRF966) GaAsFET transistor. It is protected from the several Watts of 70-cm power a few inches away by a half-wave transmission line trap etched into the circuit board. The front-end bandwidth is defined by a three-stage helical filter with a 2.8 MHz bandwidth centered at 145 MHz. The 2-meter signal is down converted to an IF of about 45 MHz in a dual-gate MOSFET (40673) mixer driven by a 2-stage 100-MHz crystal controlled local oscillator. The 45-MHz IF is then split by emitter followers to drive the FM IF/detector strips.

The core of the receiver is the Motorola MC3362 single-chip FM detector receiver, coupled with a stock NDK crystal filter centered at 10.7 MHz. Multiple channels of MC3362s convert the 45-MHz IF into data bits suitable for the CPU. A big part of the "magic" of the MC3362 comes from

Microsat Frame Function (listed from top to bottom)

	PACSAT and LUSAT	DOVE	WEBERSAT
(+Z)			
Module 05	FSK Packet Receiver	Command Receiver	Camera Module
Module 04	This Space For Rent	Flight Computer	Flight Computer
Module 03	Power Module	Power Module	Power Module
Module 02	Flight Computer	D/A Buffer/Converter	FSK Packet Receiver Voice Synthesizer
Module 01	BPSK Packet Transmitter	FM Voice Transmitter	BPSK Packet Transmitter
(-Z)			

Note that apart from the Power Module in the center position, other modules may be placed in any slot.



Jose Machao demonstrates installation of the MicroSat solar protective covers on the structural qualification model of the spacecraft in the Boulder, Colorado facility where satellites are being assembled. (Photo by Jeff Zerr)

the use of the very steep skirted 10.7 MHz crystal filters with 15 kHz bandwidth and 80-90 dB out-of-band ultimate rejection. Each MC3362 chip contains two crystal oscillators. The first oscillator in the 35-MHz range converts the desired channel frequency to 10.7 MHz to match the crystal filter. The second oscillator at 8.9 MHz converts the signal to the 1.8 MHz-frequency used by the FM discriminator.

The MC3362's FM detector drives two matched data filters, each of which uses one section of a TLC274 CMOS op amp; the 2-pole Butterworth filters are optimized for 1200 and 4800 BPS data rates. A CD4066 analog switch selects the output of one of the two filters to drive the data clipper section of the MC3362. The appropriate filter for each of the user uplink channels is selected by the OBC through the AART.

Another section of the TLC274 produces an analog signal in the 0-2.5V range corresponding to the user's frequency (the "discriminator meter") and another produces a 0-2.5V analog signal corresponding to the user's signal strength (the "S meter").

Each of the IF sections (MC3362 plus crystal filter plus crystals plus data filters plus telemetry signal conditioning plus 4066 gate) occupies about 1.5inches by 3.0 inches of space on the receiver circuit board and each consumes about 20 mW (4mA at 5V) of power.

The receiver modules designed for PACSAT have been made easily reproducable, and require very few "twiddles." **All components, including the coils and helical filter are off-the-shelf items** purchasable from sources like Digikey. It is anticipated if there is enough interest, that TAPR and/or AMSAT will make single-channel receiver kits available for use in dedicated packet link applications.

The PACSAT uplink passbands are divided into four 16-kHz channels each, spaced at 20 kHz in the 2-Meter satellite band (145.800 to 146.000 MHz). AMSAT-NA, LUSAT, and WEBERSAT all have one of their uplinks on a common frequency to simplify ground stations in certain instances. Two different modulation schemes are planned and each of the uplink channels may be set independently to receive FSK uplinks at either 1200 or 4800 bits per second by the flight computer or from ground command. At 1200 bps the bandwidth of the uplink signal is approximately 4 kHz. At 4800 bps, the uplink signal approximately fills the entire 15-kHz channel.

All users need to keep their deviation down. If your transmitter is set to about 3-kHz deviation, then your 1200 bps bandwidth will be about 5-6 kHz. Too much deviation means no signals will get through the filters. The 5-kHz bandwidth plus the Doppler offset for uncorrected transmitters will just make it through the receiver filters.

At 4800 the bandwidth is more like 10 kHz and users must adjust their uplink frequencies to cancel the Doppler.

The 1200-baud Manchester FSK modulation is compatible with existing FUJI-OSCAR-12 modems and is intended for use those stations who have FUJI-OSCAR-12 PSK modems. These stations need not vary their uplink frequency according to the satellite's Doppler shift, since the passband of each channel is wide enough to accommodate Doppler plus the narrow 1200 baud signal. 4800 baud FSK, however, requires more bandwidth, so users of this baud rate must precompensate their uplink frequency to remove the Doppler shift. It is expected that the 4800-baud FSK uplink will be used primarily by gateway and mail forwarding stations.

Also housed on the receiver board is signal conditioning electronics for an infrared sensor mounted on the top of the PACSAT and LUSAT spacecraft. This detector has about an 8-degree field of view and can be used for spacecraft attitude determination. The gain of this sensor can be changed under control of the OBC in 16 steps via the AART.

Transmitter Modules

Two different transmitter modules are under development. They are a Binary Phase Shift Keying (BPSK) Module which will be used to transmit digital data to the ground, and the Telemetry Voice Transmitter Module (TVT) to be used to transmit conventional 2-Meter FM audio to the ground.

Each transmitter contains a state-of-the-art high efficiency power amplifier powered directly from the unregulated battery supply bus thereby eliminating power losses in a voltage regulator. When the transmitter is running at high power, it is possible that total power drain may exceed the six watts of power supplied by the solar cells. A power control circuit has been devised that will allow the transmitter to operate at 16 reduced power levels between 0 and 4 Watts. The transmit power level may be set either by direct ground command or by the OBC.

Each transmitter module contains a pair of transmitters. Should one fail, the other can be commanded into operation. There will be slight differences between the two transmitters to allow for some experimentation. For example, in the BPSK modules, one transmitter will operate with straight PSK modulation while the other will use raised-cosine modulation which exhibits lower information harmonic content. Ground stations using gain antennas may false lock on the second harmonic subcarrier energy from the straight PSK transmitter. Should they do so, the result will be gibberish. Raised cosine, on the other hand, suppresses "out of band" modulation products, concentrating the energy in the main information sidebands, as desired. This results in "compatible PSK."

The second harmonic subcarriers from the straight PSK transmitter are only 14 dB below the main lobe. As the second harmonic subcarriers of the raised-cosine transmitter, are 38 dB below the main lobe, the incidence of false lock among raised-cosine modulation receivers will be greatly reduced.

The first TVT will be flown on DOVE, which carries a narrowband FM audio transmitter driven by a voice synthesizer. The transmitter will mainly be used to transmit voice synthesized or digitized audio data, however, the satellite may transmit telemetry, bulletins and text in a digital 1200 bps ASCII AFSK Bell 202 tone compatible format. These tones are compatible with those used by UOSAT-OSCAR-9 and should be capable of being

demodulated by a PK-232 terminal unit.

The LUSAT, PACSAT, and WEBERSAT transmitters all contain BPSK modules. All transmissions are digital, NRZ-I, BPSK, HDLC, and will be compatible with the AX.25 Level Two protocol now in widespread use in the Amateur Radio service. They must however be received by a PSK demodulator as used for receiving FUJI-OSCAR-12 not a conventional FSK TNC as used on 2-meter or 70-centimeter packet. This means that stations having modems to operate FUJI-OSCAR-12 are ready for the PACSATS and WEBERSAT.

The FUJI-OSCAR-12 PSK modem is an add-on to a standard TNC-2, where it connects to the modem disconnect plug. Stations with the AMSAT-OSCAR-13 modems can use them only to recover telemetry from AMSAT-OSCAR-13. There is a difference between the FUJI-OSCAR-12 PSK demodulator and the AMSAT-OSCAR-13 PSK demodulator. They are *not* compatible. The former is for 1200 baud, the latter is for 400 baud. The former can be purchased as a kit from TAPR, the latter cannot.

LUSAT, PACSAT, and WEBERSAT will transmit binary phase shift keying (BPSK) modulation in the 70-cm Amateur band. Data rates supported are either 1200 or 4800 bits per second corresponding to transmitted bandwidths of approximately 4 kHz and 15 kHz.

The reasons for the choice of Manchester FSK at 1200 baud and straight FSK at 4800 baud are as follows. The use of HDLC on the baseband data ensures (through bit-stuffing) that the fundamental frequencies in the baseband data are between 75 Hz and 600 Hz for a 1200 baud data stream. These frequencies do not pass through a normal SSB filter. Manchester encoding amounts to a DSB modulation around a 1200-Hz carrier, shifting the spectrum right into the center of the SSB filter. With four times the data rate at 4800 baud, the baseband frequencies are four times greater: 300 to 2400 Hz. This is exactly the passband of an SSB filter, so no Manchester encoding is necessary or desired.

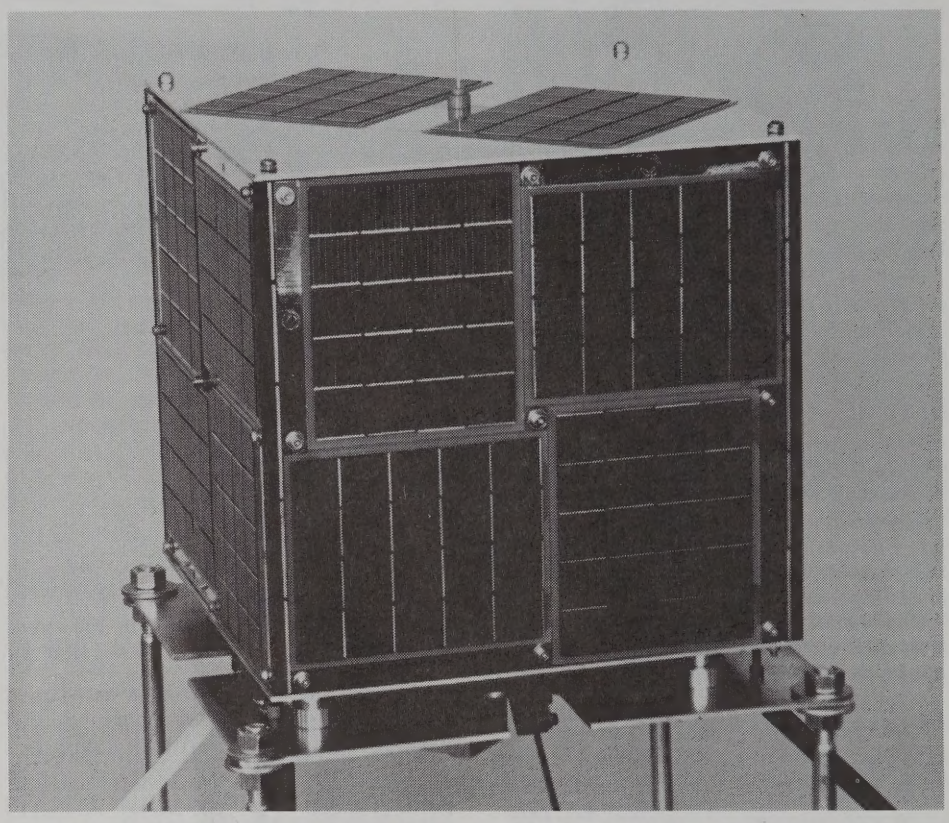
The choice of FSK encoding is made on a per-channel basis under software control. The Harris chip used for demodulation provides an appropriate matched filter for either baud rate on command.

This will permit some channels to be operated at 4800 baud for the use of gateways while others are operated at 1200 baud for user stations.

The DOVE will transmit a narrow-band audio or Bell-202 compatible FM signal in the two-meter Amateur satellite band (145.8-146.0 MHz). Its bandwidth will also be less than 20 kHz.

The 2-Meter transmitter on DOVE is 82% DC to RF efficient. The BPSK (no spectrum control) is 72% and the Helaps is 64% efficient. Even at 64%, this is the most efficient transmitter we have ever flown.

The downlink frequencies chosen for LUSAT, PACSAT, and WEBERSAT are selected to minimize functional interference and particularly to inaugurate occupation of the upper MHz of the 70-cm satellite band of 435-438 MHz.



AMSAT-NA MicroSat bus, seen here on the mounting plate, is a cube 23 cm (9 inches) on a side weighing 10 kg (22 pounds). The standard bus can be outfitted with various mission-specific payloads such as packet radio transponders, CCD cameras, etc. (Photo by Dick Jansson, WD4FAB)

Payload Modules

Each of the payload modules operates under control of the OBC which also controls the satellite itself. The OBC will perform the following tasks.

Power Subsystem Management

The BCR solar array set-point must be adjusted to obtain maximum power from the solar arrays. In addition, the power level of the transmitter must be adjusted so that the power budget as averaged over an entire orbit or over entire days, including the 34% or so of the orbit when the MicroSat is in eclipse and is net positive.

Telemetry

The telemetry for each mission will provide information related to the health of the satellite. When it comes to telemetry, these spacecraft are markedly different from the ones we have flown before. The concept of fixed "telemetry channels" is the *wrong* way to think of it. Software control of the distributed multiplexer not only provides a huge number of "channels" but allows the downlink display sequence and formats to be changed depending on mission requirements at any particular time.

There are as many as 200 possible telemetry points. **The idea of a fixed frame is and should be obsolete.** The software does not contain fixed telemetry frames and will instead identify each telemetry value with a unique identifier thus giving the greatest versatility to the command stations in choosing what they wish to see.

The telemetry list will be published in the form of a three character field where the leading character (either a digit or letters like R for receiver, T for transmitter, B for battery etc.) denotes the source module and the second digits are the address of the module's multiplexer.

Telemetry will be downlinked either in unconnected beacon packets or to connected user stations. DOVE telemetry information will also be available via the voice synthesizer.

Packet Radio

For LUSAT, PACSAT, and WEBERSAT, NRZ-I bitstreams from the HDLC decoders to the computer and similar bitstreams to the HDLC encoders from the computer

will be managed in software to implement the AX.25 protocol, the Amateur Radio version of the X.25 packet switching protocol. Unconnected beacon packets will transmit telemetry, satellite information, and bulletins. User stations will be able to connect to the satellite to query operating status and obtain additional telemetry outputs in varied formats. The satellite receivers gather signal strength and frequency offset information which can be made available to the user and which can be used in maintaining connection.

A packet bulletin board message store-and-forward capability will be provided on LUSAT and PACSAT so that users can connect to the satellite and upload messages for forwarding to distant users. It is also anticipated that ground based packet BBS networks will use the satellites for message forwarding.

Voice Synthesizer and Analog to Digital Buffer/Converter Module

DOVE will contain a voice synthesizer to convert text stored in the computer memory into plain language for modulation of the FM transmitter. The text will be stored in computer memory on upload from the ground. The text will be uploaded in the form of digitized voice in packets because there is no analog receiver.

A digitized voice or sound capability will also be implemented using digital to analog converters. Text or sounds stored in memory in this mode may be reproduced with great clarity and will contain audible measurements of various spacecraft electrical parameters, forming a voice telemetry system. After the sequence of telemetry parameters has been repeated several times, the OBC will interrupt the telemetry sequence and forward a stored voice announcement to the voice synthesizer. After the completion of the announcement, telemetry will resume. This cycle will repeat continuously, however, multiple announcements can be stored and cycled, one after the other, during the announcement window.

Announcements in English, Portuguese, Spanish, Russian, and other languages are intended.

The WEBERSAT will use application software to control the camera and store picture data. WEBERSAT is more experimental in nature than the others and it is intended that the satellite be used as a software test bed for various digital video experiments.

The Video Module

The primary payload aboard WEBERSAT is an experimental low resolution TV module. The TV module is a collection of experiments designed and built by students from the Center for Aerospace Technology at Weber State College in Ogden, Utah.

The experiments are:

1. A standard miniature CCD color TV camera modified to operate in a vacuum.

2. A spectrometer sensitive from 300 microns to 1100 microns.

3. A 1265-MHz ATV receiver.

The data generated by each of the three experiments are digitized and loaded into the bank-switched 2-Megabyte memory area of the computer. The digitizer sampling rate can be varied from 2.4-khz to 10 MHz.

The TV Camera Experiment

The TV camera is a Sony Ci-10 product. It produces a standard color NTSC analog signal which is digitized at a sampling rate of 10 MHz. The CCD element in the camera has a resolution of 780 X 490. It is estimated that when the camera is pointing toward the Earth, pictures will be taken of a ground area about 350 km X 350 km with the lens to be used.

The digitized television frame includes all synchronization signals, color burst and chrominance information. The picture is compressed, archived and stored in the 8-Megabyte area of computer memory. Pictures will be downlinked in compressed form. Software will be made available for the display of these pictures.

The camera will point out of a side of the spacecraft (perpendicular to the Z axis). Given the expected tumble and spin of the satellite, this arrangement provides the maximum view of the Earth. Positioned next to and on either side of the lens are two small photocells which will act as horizon crossing sensors. The purpose of the photocells on either side of the lens is to inhibit the camera from shooting the sun. The reasoning is that, if both photocells (with non-overlapping fields) are illuminated, the earth (about 135 degrees wide at that altitude) is in view and pictures can be taken. If only one is illuminated, the camera views the horizon or the sun (which is a smaller object) and the picture taking is inhibited.

The Spectrometer Experiment

The spectrometer experiment is designed to provide the spacecraft with sensing capability to offer substantial educational potential in the field of physics. Spectral reflection from the earth's atmosphere at various latitudes and longitudes is characterized by frequencies of absorption. Spectrometer data can be used to determine atmospheric components within the field of view of the device.

The spectrometer will also point out of a side of the spacecraft at 90 degrees to the TV camera. Two additional horizon sensors will be located on the side of the spacecraft adjacent to the spectrometer. They will be employed to sense the Earth in a manner identical to that described above for the TV camera sensors.

The 1265-MHz ATV Receiver

The 1265-MHz ATV receiver experiment is designed to study the value of store-and-forward capability as it applies to pictures.

The 1265-MHz ATV receiver will receive a picture uplinked in the Amateur satellite 23-cm band. The picture will be digitized and because the experiment is designed for the NTSC TV format, the requirements for storage and handling of the digitized data on the spacecraft are identical to those of the camera.

This Space for Rent (TSFR)

This module contains different payloads on each of the satellites. At the time of writing, the status is as described herein.

AMSAT-LU has a third transmitter of Argentinean construction in this module. It is a CW beacon and will be controlled by a microcomputer which AMSAT-LU is also providing. This third transmitter is

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Frequencies:

Mission	Downlink		Uplinks
AMSAT-NA	primary	437.050 MHz	145.900, 145.920, 145.940, 145.960 MHz
	secondary	437.025 MHz	
AMSAT-LU	primary	437.150 MHz	145.900, 145.880, 145.860, 145.840 MHz
	secondary	437.125 MHz	
WEBERSAT	primary	437.100 MHz	145.900 MHz
	secondary	437.075 MHz	
DOVE	primary	145.970 MHz	
	secondary	145.970 MHz	

These frequencies have been carefully coordinated in order to minimize the probabilities of mutual interference.

MISSION GOALS

The respective missions (in alphabetical order) are as follows:

DOVE Provision of an easily received signal consisting of a voice modulated beacon for educational and scientific use. Planned uses include transmission of telemetry and of Amateur Radio bulletins and messages in several languages.

LUSAT/PACSAT Demonstration of Radio Amateur commitment to extending digital communications facilities fully into the Amateur Satellite Service; provision of an easily utilized, satellite based facility for data storage and forwarding using Amateur packet radio techniques, and a demonstration of the feasibility of digital store-and-forward facilities within the Amateur Radio environment for educational and scientific purposes.

PACSAT has the additional goal of research and experimentation with specialized protocols for efficient access and utilization of digital data satellites.

WEBERSAT Provision of an easily utilized, satellite based facility for video data acquisition and storage and transmission to Amateur Radio ground stations using Amateur packet radio techniques.

All of the missions share these common goals:

1) Provision for advanced utilization of the spectrum allocated to radio amateurs by the regulating authorities of the various countries involved and the International Telecommunications Union.

2) Provision of a test bed for evaluation and validation of hardware technologies and software to be employed.

3) A demonstration to the International Telecommunications Union (ITU) that Amateurs from each organization involved have a strong interest in the use of the radio frequencies allocated to the Amateur Satellite Service for the improvement of Amateur practices and in support of the international Amateur satellite community.

All of the missions share these common constraints:

1) The cost of the satellite and ground station equipment is to be minimized.

2) The mass and size of the satellite are to be minimized recognizing that many launch opportunities are potentially available for small, lightweight satellite packages.

3) The mission will build on user equipment, techniques, and capabilities already utilized in the Amateur Satellite Service for digital or voice communications wherever possible.

selected and powered on an either/or basis with the secondary transmitter and is on the same frequency, 437.125 MHz.

The stated purpose for this payload is to bring MicroSat capability to Argentinean Amateurs who do not have packet equipment.

The number and scope of WEBERSAT special experiments is increased. In addition to the L band wideband TV receiver, there is a visible light spectrometer with an electronic shutter. It is operated and protected from direct sunlight in the same way that the camera is.

A magnetometer experiment will be included inside the experiment module. This device will have sensitivity comparable to the UOSAT "navigation" magnetometer and will be mounted in a plane formed by the Z axis and either X or Y (i. e., not in the XY plane).

A high school experiment is a piezo electric impact sensor. At the sensitivity planned, roughly two impacts per day are expected.

Another high school experiment is to measure the radioactive decay of identical Cobalt 57 specimens, one onboard the satellite and one on the ground. The purpose of the experiment is to detect the relativistic aging effects on the two objects, one in orbit and one at "rest." This experiment has not yet been cleared with the launching authority, but clearance procedures are being investigated.

AMSAT-NA will be flying an additional digital receiver and transmitter in their "TSFR" module. The uplink will be on L band and the downlink on S band, the first use of "true mode S." The antenna will be a dual-band discone mounted at the end of the two-meter receive whip. For this reason, the whip on the AMSAT-NA MicroSat will not be blade material but will be wire mounted inside a plastic rod which provides mechanical support. The radiation characteristics of the two-meter whip and discone are similar. Stations "edge on" with the + or – Z axis will experience nulls, and polarization is linear.

Data rates (thus, bandwidths and consequent doppler sensitivity) and exact frequencies for this experiment are not yet selected. The S-band transmitter will output about one Watt. The purposes of this experiment are to occupy these higher frequency satellite bands in order to continue strengthening Amateur Radio's claim to these space frequency allocations; to provide experimental high data rate inputs and outputs to the satellite; and to encourage operators to make use of these bands.

Eventually, MicroSats may be flown to support customers who need a small space for an experiment of their own, or who require store-and-forward (data collection or communications) capability. This space also opens the way for experimentation and expansion in Amateur service satellites as well.

Summary

This article has discussed the MicroSats and some of the equipment needed to make use of them. The project is still evolving and further details will be published when available.

The Road to Phase IV

(Continued from page 2)

We have already demonstrated store and forward capability in space on a limited scale by the DCE experiment on UoSAT, the store and forward capability on FUJI-OSCAR-12 and the command station links on earlier OSCARs. With the advent of the MicroSat PACSATs later this year, the sky's the limit on packet.

AMSAT is the only organization at present to have a worldwide packet-radio bulletin distribution, probably because we are also involved in pioneering packet. The bulletins originated at AMSAT HQ can be found on a BBS in nearly any place in the world within a few days. The fact that they get there well ahead of the hard copy in the mail was one of the reasons for the change in AMSAT's publications policy and the advent of the AMSAT Journal. Putting packet digipeaters and switches into orbit is going to serve the membership by getting you the information you need in a timely manner. You can even reach me as G3ZCZ@N4QQ from almost any Packet BBS in the world. Try it, now that I'm back as editor, I'd like to hear from you.

A Beginner's guide to Packet BBS Operation

By Joe Kasser G3ZCZ *

Introduction

If you want the latest AMSAT, MIR, Orbital and other space related information in real time then look to your local vhf/uhf Packet Bulletin Board System (PBBS). If you don't have packet radio equipment you are missing out on a whole facet of Amateur Radio. Packet radio has brought Amateur Radio into the information age, and the PBBS is where that information is at.

Your local PBBS has a wealth of features to offer. Not only does it give you access to bulletins, documents and programs, but it also allows you to leave messages for other people on your Local Area Network (LAN) or even anywhere else in the world. You can send messages to me and receive replies in days no matter where in the world you are located. Within a short time most AMSAT Area Co-ordinators will be able to handle requests for information via packet radio. If you have never used a PBBS, you are in for a surprise. This article tells you all about the features within the PBBS.

The vast majority of PBBS in common use around the world today use software written by WA7MBL or by WØRLI/VE3GYQ or are compatible with them. They are very similar in appearance and in their command structure when you connect to them. There are however some differences in the features that they offer and in the commands that you use to control them. These will be discussed in further detail in the article.

How to Connect to the PBBS

You connect to the PBBS in the same way as you connect to any other packet station. If you are using a minimal software set up, that means that you have to type 'C BBSCALL' where BBSCALL is the call of the PBBS. If you are using YAPP or LAN-LINK you use the Alternate C character to tell the program that you want to initiate a connect and it will ask you to enter the call of the PBBS, and then go on to try to establish the connect. Note that if the PBBS is using an SSID, such as "-1", you must use the whole call including the SSID. For example, if the PBBS that you wish to access is N8BMA-1 then you must issue the connect request to N8BMA-1 not N8BMA. The TNC will then issue a connect request to the PBBS station.

Connected to the PBBS

When the connect goes through, you will see the normal TNC message

"*** CONNECTED to BBSCALL"

followed by the "sign on" or "welcome" message unique to that PBBS. This initial message tells you something about the PBBS itself. Some typical PBBS "sign on" messages are shown in Fig. 1.

WA2PVV signed on identifying the version of the software that the PBBS is running, and then indicated that I have unread mail posted, told me who the mail was from and what it was about, and then prompted me for a command.

VE3CKU gave me a little more information. It reminded me of the last time I had logged in to it, and gave me a little bit of other information before telling me about my messages.

KE8X told me a little bit about itself as part of its "Sign On" message. It also told me something about the messages on the system.

When I logged into the WD4ELJ PBBS for the first time, it didn't know my name hence it called me "?_Name". It also gave me some information about itself and prompted me to give it my name and "home BBS" (more about that later).

NA2B's sign on message was somewhat different. It told me the frequencies that it was active on before giving me the prompt message.

WA8OOH has two "sign on" messages depending on which frequency I connected to it on. The local user port on 145.05 MHz gives a friendly welcome message, the other port on 145.01 MHz tells why it is there and requests that you use an alternate channel if you are not a BBS. Notice that the BBS identification was only shown on the 145.01 MHz port.

Each of the sign on messages have things in common but arranged differently. The SYStem OPerator (SYSOP) has the ability to customize almost all the messages that the PBBS will send to you, as you will see during the remainder of this article.

Fig. 1 — Typical PBBS "Sign On" Messages

```
[WØRLI 4.22]
You have new mail:
 Msg# TR  Size  To    From   @ BBS  Date      Title
  374 PN   205 G3ZCZ  W1IDH         Ø215/2Ø28 QSL
WA2PVV BBS>

Hello joe, Welcome to the VE3CKU MailBox from Ron in SARNIA
Last logged at Ø428 on 88Ø215.
Type H for help, L to list new messages.
You have new mail:
 Msg# TR  Size  To     From   @ BBS  Date/Time Title
  997  N      5 G3ZCZ  W8TNN         Ø218/Ø232 test
  996 PN    595 G3ZCZ  AF4K   NM8X   Ø218/Ø224 HF PACKET HOW?
G3ZCZ de VE3CKU: at Ø255z on 88Ø218 B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W,? >

[GYQ-CBBS4.4-$]
Hello joe,
Welcome to the KE8X MailBox in Trenton, MI
--** Dedicated to Traffic and ARRL Bulletins **--
Last logged at Ø423 UTC on 88Ø218, 115 active msgs, 3488 to 348Ø are NEW.
Type H for help, L to list new messages, W for additional files.
G3ZCZ de KE8X: at 1946z on 88Ø218 ?,B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W >


Hello ?_Name, Welcome to the WD4ELJ Gateway in Lynchburg, Va.
Type T to talk to Nick, If no answer, Please leave message.
Type H for help.
*** N  (name) to enter your name.
*** NH (call) to enter your home BBS.
G3ZCZ de WD4ELJ: at 1534 local on 88Ø218 B,C,D,H,J,K,M,N,R,S,T,U,W,>

[MBL-$]
NA2B PBBS - Massena, N.Y.
Multiport System: 145.Ø1, 14.1Ø7, 7.Ø93 Mhz
H = help for more details.
NNY-Net: NA2B BBS (B,H,KM,RM,S,T) >

LOCAL USER PORT 145.Ø5 - WA8OOH- WELCOME TO THE PTG PBBS
Hello Joe, Welcome to the Packet Technical Group PBBS.
From Ron in Livonia MI. Last logged at ØØ46 on 871ØØ4.
Type H for help, L to list new messages, NE for expert prompt.
Locals please use WA8OOH on 145.Ø5 Mhz or N8BMA-1 on 22Ø.52 Mhz.
You have new mail!:
 Msg# TR  Size  To    From   @ BBS  Date      Title
  553  N    184 G3ZCZ  WB8WKA        1ØØ3/1445 address
  547  N    883 G3ZCZ  WB8COX        1ØØ2/2337 reply ... LAN-LINK
G3ZCZ de WA8OOH: at Ø142z on 871ØØ4 ?,B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W >

145.Ø1 BBS forwarding only. Please use WA8OOH on 145.Ø5 or N8BMA-1 on 22Ø.52
[GYQ-CBBS4.4-$]
>
```

*Editor, see page 2 for address.

Connected But What Next?

At this point you are connected to a PBBS and it is waiting for a command to do something. Each command that it expects consists of one or two letters. Each command may or may not be followed by a qualifier. When you send a command followed by a qualifier, there should be a single space character between the command and the qualifier.

For the purposes of the article, commands will be shown enclosed in single quotes ('). You should not type the single quotes when working a PBBS. Each command should also be followed by a carriage return (Enter).

Telling it your Name

You will have noticed from the sign on messages that the PBBS likes to address you by name. I suppose that it wants to be friends with you, and in the American manner address you by your first name. The command you use to tell it your name is in the letter 'N' followed by your name. For example, I usually use

'N Joe'

to tell it my name.

When you tell it your name it will send you a reply message confirming that it has received your name and stored it away somewhere. Typical responses to the 'N' command are shown in Fig. 2.

WD4ELJ is using the WØRLI PBBS software, because that is the only one that asks for the "home BBS" and sometimes for your Zip Code. The home PBBS is entered (as prompted) by means of the 'NH' command, as in

'NH N4QQ'

if your home BBS is N4QQ.

N8FIS PBBS on the other hand is running the WA7MBL software, and not only did it confirm my name when I entered it, as shown in Fig. 2, but continues to use it each time it prompts me for a command. More about the prompt line later.

Getting Information about the PBBS Itself

If you want to know something about the PBBS, namely who the operator is, or what equipment is being used, you use the 'I' (Information) command. This command is a single letter on a line by itself. Typical responses received on-the-air from NM8X, WA2PVV, WA8ERQ, VE3CKU and WD4ELJ are shown in Fig. 3. The response from WA2PVV means that the SYSOP has not placed any information about the system in the file that is transmitted to you when you send the Information command. WD4ELJ has left the standard text (that the software came supplied with) in place and has not yet edited the file to include a description of his system.

The Command Prompt Line

The PBBS will always signal or prompt you when it is ready for you to send it a command. These prompt messages can be customized by each SYSOP and may take many forms. Each PBBS has two kinds of prompts. The short (expert) prompt and the long (novice) prompt. You can toggle from one to the other using the 'eXpert toggle' command. The command on a WA7MBL PBBS is 'X' and 'NE' on a WØRLI PBBS. Some examples of both types of prompt messages are shown in Fig. 4.

Changing the Prompt Line

Once you are somewhat familiar with PBBS operation it behoves you to switch to the 'Expert' message. You use the 'X' command on a WA7MBL PBBS or the 'NE' command on a WØRLI/VE3GYQ PBBS to toggle from one message mode to another. In either case, the PBBS remembers what you commanded it and will give you the same form of message next time you log on.

When you change to the Expert User status you may get a message something like

"You have been changed to an Expert User"

followed by the (new) short prompt message.

Listing the Messages and Bulletins.

Once logged into the PBBS, you use the 'L' command to get a list of the messages on the system. Use of the basic 'L' command will get you a list of all the "readable" messages posted on the system since you last logged in. If this is your first time, it may get you a list of every message on the system or it may get you a response telling you that there aren't any messages posted. Fig. 5 shows some typical message listings. You can only read public messages or private ones addressed to you.

The first column shows you the message number. The second one tells you what the type and status of the message is. The third column tells you how big the message is. The remaining ones tell you who sent the message to whom, when and what it is about.

The message number is the key to reading the message. You MUST refer to all messages by their number.

The type of message is indicated by the two letters in the second column. The two PBBS software packages differ somewhat in their use of designator letters.

The first column tells you what kind of message it is, these are referenced by letters as shown below.

A. ARRL bulletin.
B. Other type of Bulletin.
F. Special message type,
is not killed after Forwarding.
P. Personal/Private message.
T. Traffic Message

The second column tells you something about the status of the message, also referenced by letters as shown below.

F. The bulletin has been Forwarded.
H. A message that has been Held.
N. Message has Not been
read/forwarded.
O. Old message.
Y. Yes, message has been read.

The Size column tells you how many characters are in the message. This will give you an idea of how long it will take to read it, or how much space you will need on a disk if you want to capture it and save it.

The next three columns tell you who the message is to, who sent it, and if it is to someone on a different PBBS, which PBBS the destination station is expected to read the message on. The software in the WØRLI and WA7MBL PBBS put the source station and destination PBBS in different positions in the listing. It should however

Fig. 2 — Typical Responses to the 'N' Command.

```
*** Done.
*** NH (call) to enter your home BBS.
G3ZCZ de WD4ELJ: at 1535 local on 880218 B,C,D,H,J,K,M,N,R,S,T,U,W,>


*** Done.
G3ZCZ de WD4ELJ: at 1536 local on 880218 B,C,D,H,J,K,M,N,R,S,T,U,W,>


64 Msgs. - Next, New User ->
*** Your NAME is entered as: Joe
64 Msgs. - Next, Joe ->


Oh, Hello Joe
WA3PXX BBS (B,D,H,I,J,K,L,N,R,S,T,U,V,W,X,Y,?) >


*** Ok Joe it's done, what next ?
*** Please use the NH command to enter the call of your local BBS.
G3ZCZ de AK3P: at 2019z on 880306 B,D,G,H,I,J,K,L,N,P,R,S,T,U,W >


Welcome to the ARINC Radio Club BBS, Joe
W3ZH BBS (B,D,H,I,J,K,L,N,R,S,T,U,V,W,X,Y,?) >
```

Fig. 3 — Typical Responses to the 'I' (Information) Command.

```
  NM8X is operating WØRLI/VE3GYQ PBB version 4.3 on a WYSE 80386
computer with 2048k Ram and a 44 Mbyte hard drive.

  This system is a general purpose packet radio server node. It
supports message store and forward, file upload/download, and
also information about stations heard or connected.  This mail
and file server is part of the ON1E/ON1W, ON1S/ON1N and
ALLMI/SEMICH networking system.

   Normal PBBS operating time is 24 hours a day.  The PBBS is
accessible by manual-keyboard users via a maximum four-digipeater
link on 145.03 and 145.09.

   Mail-only ports are not used but forwarding is done on 145.09
and local users are also urged to use 145.09 whenever possible to
ease the load on 03 and allow that frequency to be used for point
to point communications.

   TNC's in service on all ports are kantronics KPC-2's and
Radio's on both 2 meter ports are Kenwood TM-2570's.

   Antenna's are an AEA Isopole at 95 ft on 03 and an AEA Isopole
at 60 ft on 09.

   For further information, leave a message to NM8X,N8HTG,NT8V or
VE3CKU.  (Sysops) on this PBBS.

Have Fun DE:

NM8X    Jim         519-542-8529
N8HTG   Lee         313-987-6821
NT8V    Roy         313-987-6821
VE3CKU  Ron         519-336-1112

G3ZCZ de NM8X: at 1335z on 880217 B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W,? >

*** File not found: \mb\bbs\info.mb
WA2PVV BBS>

   This PBBS is a three port system that provides store and
forward message handling, forward and reverse automatic mail
forwarding, as  well as  ASCII and binary file storage, retrieval
and transfer.

   Normal PBBS operating hours are 24 hrs daily.  The PBBS is
accessible by local manual-keyboard users via a maximum five-
digipeater link on 145.010 MHz and a maximum of eight-digipeaters
on 145.05.

    TNC's in use are MFJ's 1274 on HF and 1270 and PK 80 on VHF
rigs on VHF are both Azden 3000 running 10 watts to a Mirage b
1018 amp , ant is a Ringo Ranger at 65 ft. RIG on HF is a Kenwood
530 S running 200 watts pep to a Wilson Trap Vertical at 40 ft

                        This system is open to all.
                             ENJOY THE SYSTEM
                                   73
                                 DICK
 Mid-Net BBS>

This system is a general purpose packet radio server node.
It supports message store and forward, file upload/download,
GateWay linking between the radios, and information about
stations heard or connected.

  *** Put a nice description of your station here ***

G3ZCZ de WD4ELJ: at 1539 local on 880218 B,C,D,H,J,K,M,N,R,S,T,U,W,>

    VE3CKU is operating WØRLI's version 4.30 BBS, on an XT Clone
with a 20MB harddrive, and two COM ports.  VE3CKU is part of the
ON1W/ON1E/ON1N/ALLMI/SEMICH Networks.

    VE3CKU-BBS has two ports, the 2-meter port on 145.090
consists of a Kenwood TR-7200A, putting 10 watts into a mobile
whip at 95ft.  The 220.520 MHz port consists of a Kenwood TM-
3530, a 75ft feedline up to the VE3SUR repeater cabinet in the
rooftop radio room, then a Mirage C3012 amplifier/preamplifier
puts out 100 watts to a 7 element beam at 140ft. The beam is
fixed/aimed at Detroit.  Both TNC's are Kantronics KPC-2's, and
the radios are equipped with time-out timers.

    Both ports are operated 24 hours a day, and up to 4
digipeaters may be used for access. Primarily VE3CKU-BBS is for
automatic mail forwarding and distribution of bulletins, etc., on
the network. Users are incouraged to check into NM8X-9/NM8X-3/or
NM8X-2, to receive full BBS services, download files, and read
mail.
                                          Remote Sysop's:
HAVE FUN !  de Ron VE3CKU                    Jim - NM8X
                                             Lee - N8HTG
                                             Roy - NT8V


G3ZCZ de VE3CKU: at 0255z on 880218 B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W,? >
```

be easy to figure out which is which.

There is a category of messages called bulletins. These are general interest messages and are sent to many PBBS's along a route or distribution chain. For example, a bulletin may be to AMSAT and originate at W3IWI or N4QQ. Others may originate at the ARRL and be posted at W1AW. The Bulletin may then go from PBBS to PBBS until it gets to Detroit, Florida, or to Alice Springs in Australia. These bulletins usually show up as messages to "ALL" along distribution routes which show up on the BBS column in the form of AMSAT, ARRL, USA, EU (Europe), NEOH (North East OHio), RT5N (RouTe 5 Northbound), SEMICH (South East MIchigan) and ON1W (Ontario, Westbound).

The 'L' command has some qualifiers to let you control which of the messages are listed on your screen.

If you follow the 'L' command by a number it means that you want a list of messages with message numbers equal to or greater than the number you sent. For example if you send 'L 200', you will get a list of all readable messages with numbers greater than 200 as well as message number 200. This means that the listing of messages shown for GB3HQ in Fig. 5 could have been obtained by the command 'L 1028'. (Just to confuse you, it could also have been obtained if the message posted when you last connected to GB3HQ had been message number 1027). On a WA7MBL PBBS you can also get a listing of messages between a range of numbers. For example the command 'L 1028 1032' will get you a list of anything readable with message numbers between 1028 and 1032.

'LM' (List Mine) will get you a list of messages associated with your callsign. On a WØRLI PBBS you will get a list of all messages that you have sent and are still posted, and all incoming messages to your callsign posted on the PBBS that you have not yet read. On a WA7MBL PBBS you will get a list of all INCOMING messages even if you have read them. This is a good feature because it will remind you that old messages are still posted and to delete them.

The 'LN' (List New) command on a WA7MBL PBBS will give you a list of the New or unread messages.

'LT' (List Traffic) will get you a list of the NTS traffic messages posted.

'LL' (List Last) followed by a number. For example to read the last 100 messages posted you'd send 'LL 100'.

You can get a listing of messages posted to a different PBBS or to a routing list by using the 'L @' command. For example

'L@ AMSAT'

would get you a listing of all bulletins posted along the AMSAT routing route.

You can also get a listing of public messages posted to or from a particular callsign by using the 'L>' and 'L<' commands. Note the way the arrow is

Fig. 4 — Typical examples of the Prompt Line.

```
G3ZCZ de NM8X: at 0459z on 880216 B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W,? >
G3ZCZ de VE3CKU: at 0438z on 880218 B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W,? >
N4QQ BBS (B,H,KM,RM,S,T) >
NNY-Net: NA2B BBS (B,H,KM,RM,S,T) >
Mid-Net WA8ERQ BBS>
WA2PVV BBS>
N4QQ BBS>
1138, 24 msgs>
 Mid-Net BBS>
64 Msgs. - Next, Joe ->
WA8YWH BBS>
Select option B,H,J,K,L,N.R,S,X >
```

pointing. 'L> CALL' will get you a listing of messages to a callsign, and 'L< CALL' will get you a listing of messages from the callsign.

Reading Messages.

Having listed the messages you probably want to read a few of them. To read a message you send the 'R' command followed by the message number. The command 'R 1040' will get you the contents of message number 1040. The WA7MBL PBBS software allows you to ask for up to six messages at a time. So for example you could send the command

'R 1027 1234 1345 1029'

to read four different messages.

If you have a number of messages posted, you can ask for them all using the 'RM' (Read Mine) command. On a WØRLI PBBS then 'RM' command will get you the contents of any unread messages. To do the same job on a WA7MBL PBBS you'd have to use the 'RN' (Read New) command. On a WA7MBL PBBS the 'RM' command will get you the contents of all messages posted to you on the PBBS.

Messages and bulletins are prefixed by headers which show how they got from the sending PBBS to your PBBS. These headers can be seen in short or verbose listings as shown in Fig. 6.

The 'R' command shows the message headers in their condensed or short form version. The WØRLI PBBS lets you see the full headers if you use the 'RH' command. The WA7MBL PBBS also allows you to get a display of the full headers in the message path routing, using the 'V' (Verbose) Command. You may also use 'VM' and 'VN'. Fig. 6b shows the expanded path routing which not only shows you which PBBS's the message came through but also gives you date/time data for each section of the link as well as usually telling you the message number each PBBS assigned to the message and something about the the PBBS itself.

Sending Messages

To send or post a message you use the 'S' command. The PBBS allows you to post different types of messages. You may send personal/private or public messages. Personal messages can only normally be read by the person they have been sent to. Public messages may be read by anyone. You can send NTS traffic, you can post bulletins, and best of all you can even send messages to someone on another LAN, even if that person is out of state or even across the country.

To send a message you just use the command 'S CALL' where 'CALL' is the callsign of the station you are sending the message to. If you are sending the message to someone on another PBBS you'd use the command 'S CALL @ PBBS'. If it was a private message you'd use 'SP CALL'. For example if you wanted to send me a comment on the *AMSAT Journal* you'd use the command

'S G3ZCZ @ N4QQ'.

This command tells the PBBS that the message is going to G3ZCZ who usually checks into the N4QQ PBBS for his messages. When the PBBS receives the command it will send you a reply asking you for the subject of the message. This is the part that describes the contents (a summary) and also shows up in the header and in the listing of messages (the 'L' command).

The request for the subject may take different forms. Typical off-the-air examples are

"Enter title for message:"
"Enter Subject for Msg # 15382:",
"Message Subject (City, State or Country if not local):"
and "Sj:"

Enter the subject of the message but keep it short. It must fit in that column in the listing.

When the computer has accepted the subject, it will ask you to enter the message. The request may take the form of

"Enter message, ∧Z (CTL-Z) or /EX to end,
it will be message 781"

Fig. 5 — Typical PBBS Message Listings.

```
Msg# TR  Size  To    From   @ BBS  Date      Title
 362  F  1123 N2CEH  KM2H   N2EZG  0215/1207 220 WRAP
 358 FH   905 ALL    N1API  RT5N   0215/0629 Need 2 Meter Amp Help
 354  N   682 ALL    W1ETH         0214/1655 Corrected Apple HELP!!
 348 FN  2176 ALL    WB2HBZ WA8YWH 0214/1453 Boulder Co., CO, War on Amateurs
 327 FN  1290 ALL    N2GBT  RT5N   0214/0638 BLIND AUCTION COMING UP ..
 326 FN  1281 ALL    WA2MOE RT5N   0214/0637 ARRL #16 Western Sahara
 325 FN  8578 ALL    WB2HBZ RT5N   0214/0633 Sweden Calling DX 1977 2-09-88
 324 FN  3772 ALL    WB2HBZ RT5N   0214/0630 Another PC Virus-Part 2
 323 FN  8016 ALL    WB2HBZ RT5N   0214/0627 Another PC Virus-Part 1
 315 FN  2377 ALL    WB2HBZ RT5N   0213/1942 Boulder Co., CO, War on Amateurs
WA2PVV BBS>

Msg# TS  Size TO     @ BBS  From   Date    Subject
1084  N    41 G3OUF        G4MTPM 17-Aug  hi
1082  N   204 ALL          G1UWS  17-Aug  SWOP ATARI ST
1073  N   187 G8KXW        G3PAQ  16-Aug  Welcome
1072  N    43 G4LZK        G4FFC  16-Aug  HELLO TED
1068  N   466 ALL          G1BFV  16-Aug  Radio Database
1067  N   138 ALL          G1SLS  16-Aug  REF.PK232 DRIVER FOR BBC/MASTER
1054  $   770 ALL          G1HUL  16-Aug  **** SCOUTING USERS GROUP *****
1051  N   304 G3UEG        G3AAJ  15-Aug  S
1042 A$  4201 ALL          G3RWL  15-Aug  New FO-12 Mailbox commands (warning
1041 A$  1282 ALL          G3RWL  15-Aug  DON'T use Oscar-10
1028 B$   138 SYSOPS       GB3RA  15-Aug  G1AWD BBS IS NOW GB3RA!!
GB3HQ BBS>

Msg# TS  Size TO     @ BBS  From   Date    Subject
 480 BN  5819 ALL    @NEOH  K3RC   18-Feb  Exam sites in Ohio
 479 FN  8013 ALL    @NEOH  KA4BCD 18-Feb  W5YI Report 2-15-88  3 of 3
 476 AF  2344 ALL    @NEOH  W8PH   18-Feb  OHIO SECTION BULLETIN NR 7
 475 FF  5428 ALL    @NEOH  KA4BCD 18-Feb  W5YI Report 2-15-88  1 of 3
 474 FF  6580 ALL    @NEOH  KA4BCD 18-Feb  W5YI Report 2-15-88  2 of 3
 473 FF  6083 ALL    @NEOH  KA4BCD 18-Feb  W5YI Report 2-15-88  3 of 3
 470 BN   878 ALL    @WA8YWH WB2VPH 18-Feb MIDI interface for IBM/Commodore
 469 BN  1231 ALL    @WA8YWH WB2VPH 18-Feb WinterFest!!!!!!
 468  N  1135 ALL    @WA8YWH WB2VPH 18-Feb Luking 4 Azden PCS2800
 467  N  1198 ALL    @WA8YWH WB2VPH 18-Feb GE 4EG21A11
 466 BN  1455 ALL    @WA8YWH WB2VPH 18-Feb Ka Node Owners
 465 FN  1944 ALL    @WA8YWH WB2VPH 18-Feb Portable C-64
 464 FN  3670 ALL    @WA8YWH WB2VPH 18-Feb Contester's Diet
WA8YWH BBS>
```

Fig. 6 — A Typical Message.

```
(A)          Condensed Path display

Msg # 9  Type:F  Stat:F  To: ALL    @ON1W     From: NF6K     Date: 30-Jan/0535
Subject: AEA PK-232 Modifications

Path: VE3GYQ!VE3EUK!VE3KOI!W2ICZ!KA2VTY!N2EPO!KC3BQ!N2EZG!N1BCK!N2AYY!WB2HBZ-1
      !WB2QJA

(B)          The expanded or verbose path.

R:870127/0407z @:VE3GYQ London, ON #:4920 O:NF6K
R:870128/2232z @:VE3EUK Kitchener ON #:218 O:NF6K F:145.01/145.09
R:870128/0421z @:VE3KOI Milton, ON #:469 O:NF6K F:145.01/145.03
R:870127/1015z @:W2ICZ Buffalo NY #:172 O:NF6K F:HF/145.01
R:870127/0827z @:KA2VTY Elba, NY #:198 O:NF6K G:FN03 F:145.01/59 P:716
R-870127/0124e @:N2EPO  Churchville, NY #:  538 O:NF6K   G:FN13 F:145.01 P:716
R:870127/0531z @:KC3BQ Skaneateles,NY #:5265 O:NF6K P:315 F:145.01/03
R:870127/0312z @:N2EZG Alpine,NY #:1032 O:NF6K G:FN12 P:607 F:145.01/.07
At N1BCK :    66 From NF6K   Rcvd 870126/2013, Sent 870127/0317
R:870126/0717z @:N2AYY  Glens Falls NY #:3163 O:NF6K
R:870124/1619z S:870126/0715z WB2HBZ-1, Kinnelon, NJ   184 < NF6K   (!201)
At WB2QJA:   758 From NF6K   Rcvd 870124/0937, Sent 870124/1120
```

or "Send message. Use CTRL-Z or /EX to end:"

or even just plain "Msg:".

At this point you enter the text of the message. When you have completed the message, enter a 'control Z' character (depress the control key and the Z key at the same time) and then depress the 'Enter' key. After a few moments the computer will confirm reception and storage of the message by giving you the regular prompt message.

If you are sending a message to someone at another PBBS and you think that the PBBS SYSOP won't know how to route the message, put the routing information in the subject of the message or send the System Operator (SYSOP) a message telling him where the destination PBBS is located. For example, if you were sending a message to G3ZCZ @ N8BMA the subject would be "short description [Detroit MI]" which would tell the SYSOP and any others along the way, that the message is going to Detroit in Michigan.

In the examples shown above you may have noticed that the PBBS gives you the message number for you to refer back to later.

To send a bulletin to everybody on a routing list or to everyone at your local PBBS you have to use the 'SB' command. Thus

'SB ALL'

would post a bulletin to everyone on the PBBS. If you want to post the bulletin so that it is distributed along a routing list, you'd put the routing list as the destination PBBS such as

'SB ALL @ AMSAT $'.

The '$' after the routing designator tells the PBBS to assign an specific identification to your bulletin. It is part of a scheme to minimize transmissions of duplicate copies of the message. Routing lists take the form of AMSAT, EU, ARRL, USA, RT2S, ON1W, SEMICH and ALLOH. If you want to know more about routing lists, post a message to your local SYSOP asking what ones the PBBS is linked to.

Killing Messages

Now that you can see what messages are posted, read and send them, you also have to learn how to kill or delete some. Once you have read your messages, delete them from the PBBS. The 'K' (Kill) command is used to kill messages. If you want to kill all incoming messages at once, use the 'KM' command. If you do so, *make sure you know exactly which messages are there.* Depending on the PBBS software *it's very easy to delete messages before reading them !* It is far better, but longer to selectively delete each message. You delete a single message using the command 'K number' where number is the number of the message to be deleted. For example to delete message 234 you'd type the command

'K 234'.

Files

The PBBS allows you to upload and download text or ASCII files. Files are usually stored in sub-directories. The 'W' command is used to see what sub-directories are available on the PBBS.

This command performs the same function but the information presented to you by the PBBS is different on a WØRLI BBS than on a WA7MBL BBS.

Files on a WØRLI PBBS

When I connected to NM8X-3, (WØRLI PBSS) and sent it a 'W' command, it returned the screen shown in Fig. 7a.

It told me what directories were available. I wanted to look at the "Equipment Mods" subdirectory, so I sent it the 'WL' command to get a listing of the 'L' sub-directory. I then received the reply shown in Fig. 7b.

This listing told me not only what the files are, but also how long they are, and also gave me some information about NM8X's hard disk, before giving me back the prompt message.

As I wanted to look at the PK-232.MOD file, I sent the command

'DL PK-232.MOD'

'D' is the command to download a file. It is always followed by the letter code for the sub-directory and the name of the file.

Uploading Files to a WØRLI PBBS

To upload files you use the 'U' command with the directory and file name qualifier. In the example shown in Fig. 7, you are only allowed to upload files into the 'A' subdirectory. To upload a file such as "G3ZCZ.LAN" to the PBBS you'd have to send the command

'UA G3ZCZ.LAN'

and follow the instructions on how to begin and end the file transfer.

Fig. 7 — Files on a WØRLI PBBS.

```
(A)          An Example of the Root Directory Listing.

Use W and directory ID:
WA All files must be uploaded to this area   EXAMPLE    UA Filename
WB Address's                          Download only area.
WC ARRL Bulletins                     Download only area.
WD Basic Ascii Programs               Download only area.
WE BBS Information                    Download only area.
WF Misc. Bulletins                    Download only area.
WG CRRL Bulletins                     Download only area.
WH Humor                              Download only area.
WI Other Information                  Download only area.
WJ Misc. Whatever                     Download only area.
WK Maps                               Download only area.
WL Equipment Mods                     Download only area.
WM Pictures                           Download only area.
WN Model 100 Programs                 Download only area.
G3ZCZ de NM8X: at 0509z on 880216 B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W,? >


(B)          The Equipment Mods. Subdirectory Listing.

AEA-RF.MOD      1k ¦ KPC2CLK.MOD     3k ¦ TNCFILTE.MOD    1k
ICOM02.MOD      6k ¦ MFJ.MOD         2k ¦ YAISU726.MOD    2k
KPC-2.MOD       1k ¦ PK-232.MOD      2k

18k of 41396k used, 20552k free.

G3ZCZ de NM8X: at 0511z on 880216 B,C,D,H,I,J,K,L,M,N,P,R,S,T,U,V,W,? >
```

Files on a WA7MBL PBBS.

The WA7MBL PBBS uses the same file directory structure as does DOS (the Disk Operating System). Thus when you send it a 'W' command you will get back a directory/file listing that looks like a DOS listing.

N4QQ uses the WA7MBL software on his PBBS. When I sent it a 'W' command I received the reply shown in Fig. 8, you can see that it contains a mixture of subdirectories and files.

Subdirectories are indicated by the "<DIR>". I then sent it the 'W Packet' command and received the directory listing shown in Fig. 8b. I further sent the 'W NTS' command and received the directory listing shown in Fig. 8c.

To download a file you'd use the 'D directory/filename' command. Thus the command to download the file "TUNING.HF" which is located in the "PACKET" subdirectory is

'D \ PACKET \ TUNING.HF'.

Don't try to download a subdirectory. You use the 'u' command to upload a file. Send the full file name including the directory you want to put it on and follow the instructions that the PBBS will give you regarding how to do it.

Talk to the SYSOP

If you want to talk to the PBBS SYStem OPerator, you use the 'T' (Talk) command. When it is received you will probably get a reply telling you that the computer is paging the SYSOP. If the SYSOP is home, and wants to talk with you, a message to that effect will appear on your screen, if not, a "Not at home" message will appear. On many versions of the PBBS software, if you send a command while the SYSOP is being paged, it will *automatically* cancel the page.

Software Version

Sometimes at connect or "log on" time you will be told which version of the software the PBBS is running as part of the welcome message. The version is enclosed in square brackets like this: []. For example, the following version codes were extracted off-the- air.

"[MBL313] WA7MBL Version 3.13" as received from GB3HQ.
"[MBL-$] WA7MBL Version 5.0" (?) received from NA2B.
"[WØRLI 4.22] WØRLI Version 4.22" as received from WA2PVV.
"[GYQ-CBBS4.4-$] WØRLI/VE3GYQ Version 4.4" as received from WA8OOH-1.
"[GYQ-CBBS4.5-$] WØRLI/VE3GYQ 4.5" as received from N8BMA-1.

If the PBBS does not give you the version when you first connect, and you still want to know, you can use the 'V' command on WØRLI software to ask it what version it is running.

Typical off-the-air responses to the 'V' command for various PBBS's were,

"WØRLI/VE3GYQ V3.22, 2 July 1987"
"WØRLI/VE3GYQ V4.3, 3 December 1987"
"WØRLI/VE3GYQ V4.5, 14 February, 1988"

Connecting Elsewhere via the PBBS

The PBBS also has a built in facility to let you connect to other stations on other frequencies, using the PBBS as a gateway. There are a number of commands associated with this mode of operation.

The 'J' command allows you to get a "Journal" list of stations that have been heard by the PBBS on any of its ports. Most PBBS's have more than one port active. This means that they operate on more than one frequency. The second or other ports provide trunking of messages from your local PBBS to other PBBS's as well as hf or vhf access from different LAN frequencies. When you send the PBBS a 'J' command it will usually reply asking you which port you want the listing of, in somewhat the following manner.

From one PBBS you may get back a list such as this one.

Use J and port ID:
JD 145.01 MHz.
JE 145.05 MHz.
JL Connected

A second BBS on the other hand may give you this one.

Use J and port ID:
JC 145.09 MHz.
JD 145.03 MHz.
JL Connected

Both PBBS's are configured differently.

When you've seen what frequencies show up on which ports you can ask it for the journal of that port by adding the port identification letter to the 'J', as in 'JC' for example. You will then get back a listing something like this.

Port C, 145.09 MHz.

WD8LIZ	0453
VE3CKU	0447
VE3WZL	0058
K8DD	0040
NM8X-9	1715
VE3RCA	1506
VE3RCA-3	2335
VE3EUK	1539
VE3KGB	1535
N8FTY	1324

To actually connect to someone, you use the 'C' command. You must also define the port letter in the command. So in the above example if you had wanted to connect to VE3RCA who had shown up in the journal on port C, you'd send the PBBS the command

'CC VE3RCA'.

The PBBS will let you know that its trying by sending you a reply which could take the following format.

"Attempting the connection on 145.09 MHz. ^W will abort"

If for some reason the connect request fails, it will tell you with a message. A typical message is shown below.

"Connection not established."

Note that the 'journal' does not distinguish between calls heard directly or via a digipeater. Also, just because a call is in the journal, don't expect the station to still be on-the-air, especially if the journal entry is old. Thus, unless you know that the call is local and active on the LAN most of the time, don't be surprised if the connection is not established.

If you just want to see what is happening on the other port you use the 'M' (Monitor) command. This will cause the

Fig. 8 — Files on a WA7MBL PBBS.

```
(A)        An example of the Root Directory Listing.

USER.DOC       3325  DOWNLOAD.HOW  1110  MAILFWD.HOW   3320  AMSAT         <DIR>
QUERY.TCP      5360  313USER.DOC    27K  DOWNLOAD.D10  1658  COSI12.87     9391
ARRLDX        <DIR>  ARRLPROP     <DIR>  NTS          <DIR>  PACKET        <DIR>
DX            <DIR>  PK232        <DIR>  VKHUMOR      <DIR>  AUTOPATC.T    3300
AUTOPATC.T40   3366  NETROM       <DIR>
 12118016 bytes free.
N4QQ BBS>

(B)        The Packet Subdirectory Listing

AX25L2.LTR     5565  AX25L2.DOC     16K  LLBBS.NGC     3441  TUNING.HF      1400
 12118016 bytes free.
N4QQ BBS>

(C)        The NTS Subdirectory Listing

KB2HM.NTS      5948  HISTORY.NTS   3559  WA7MBL        2497  LOCAL.ZIP       950
ZIP.3RN        1553  AREACODE.LTR  4005  ARRLGRAM.NUM  6537
 12118016 bytes free.
N4QQ BBS>
```

Fig. 9 — Summary of the most often used PBBS Commands.

(A)

```
Summary of the most often used WØRLI PBBS Commands.

Mail commands:
  L - LIST mail headers
  S - SEND a message
  R - READ a message
  K - KILL a message

File commands:
  W - WHAT's available (File Directory)
  D - DOWNLOAD a file FROM the PBBS
  U - UPLOAD a file TO the PBBS

Other commands:
  B - BYE (Logoff)
  I - Get INFORMATION about this PBBS
  J - Show STATIONS heard or connected
  T - TALK to SYSOP
  NE - CHANGE your "Expert" status
  V - Show VERSION of PBBS software in use
  ? - Get detailed HELP with individual system commands
  H - Get general HELP with all system commands
  Cp - Connect to CALL, using port p.
  M - Show what ports are available on this PBBS.
  Mp - Watch the packets on port p.
```

(B)

```
Summary of the Most Often Used WA7MBL Commands.

Mail commands:
  L - LIST mail headers
  S - SEND a message
  R - READ a message
  K - KILL a message

File commands:
  W - WHAT's available (File Directory)
  D - DOWNLOAD a file FROM the PBBS
  U - UPLOAD a file TO the PBBS
  Y - BINARY file transfer

Other commands:
  B - BYE (Logoff)
  I - Get INFORMATION about this PBBS
  J - Show STATIONS heard or connected
  T - TALK to SYSOP
  X - CHANGE your "Expert" status
  V - Verbose listing of message (full routing headers)
  ? - Get detailed HELP with individual system commands
  H - Get general HELP with all system commands
```

PBBS to relay any packets it hears on the specified port. Note you have to tell the PBBS which port to monitor using something like 'MA' if you want to monitor packets on "Port A".

In the early days of packet radio, the PBBS was the only gateway facility that existed to allow cross-band connects. These days with NET/ROM and KA-NODEs readily available, it is advisable not to use this feature, as there is no need to tie up the PBBS as a gateway.

Obtaining On-Line Help

Each PBBS contains on-line help information. You can get a list of the commands and features with the 'H' (Help) command. It will instruct you on how to get detailed help on specific commands. Try it. Summary command listings for both types of PBBS are shown in Fig. 9.

Logging Off the PBBS

To log off the PBBS send the 'B' (Bye bye) command. The PBBS will then disconnect from you and close its files in an orderly manner and set itself up for the next person. You can disconnect and achieve the same effect, but do it the polite way.

Summary

Lurking on that PBBS disk are electronic mail capabilities, and the electronic newspaper in the form of ARRL, CRRL, AMSAT and many other bulletins. The amount and type of information literally at your fingertips increases daily. This article has been a beginner's guide to using the packet radio BBS. It has covered the most commonly used features of the BBS. If you can follow the material presented in the article, you will be able to expand your horizons with packet radio and connect to the exciting new world of information and bulletins.

"Dear Joe..."

AMSAT-OSCAR 13 Mode "B" and "J" Transitions

Dear Joe: I am unaware of any general agreement between operators as to frequency selection when in QSO while the satellite changes from Mode B to J or vice versa. I've been cut off unexpectedly as I'm sure others have. Although I am probably aware of the coming transition down to the second, the changeover often still comes as a surprise.

I, therefore, propose the "LLO SHIFT."

When AMSAT-OSCAR 13 changes from mode J to mode B ignore the MHz portion of your receive frequency and subtract 0.060 MHz. For example if you are receiving on Mode J at 435.970 MHz, subtract 0.060 MHz and set your Mode B receiver at 145.910 MHz (970-060 = 910). Conversely when the change occurs from Mode B to Mode J, add 0.060 MHz, so for example 145.910MHz becomes 435.970MHz.

When changing from Mode B to J, it is possible to go out of the passband using this approach. In that event go to the top or the bottom of the Mode J passband depending on where you tried to go out.

I've tried this procedure several times with various operators. It sure beats "watching the clock". While 0.040 was first proposed, Jack, KA5DNP suggested 0.060 to help keep sidebanders in the upper portion of the passband and I thank him for that suggestion.

Half a dozen or so of us have tried the procedure and it seems to work FB. I think it would be interesting if a few more operators get a chance to kick it around.

Dave, WB6LLO

Meaningful Signal Reports

Dear Joe: The RST System serves our hobby well at HF. Transponders, however, are not ionized reflecting layers unaffected by the number of signals passing through them. The "signal report" of ALL the users of a transponder depends on how many users are on at a time and one overpowered user can have a remarkable depressing effect on a signal report. Somehow receiving a 5/5 report from someone who also reports that he is using a 40-element crossed Yagi antenna feeding two cascaded GaAsFET preamplifiers does not give me confidence that my transmitting system is outstanding. Similarly when I receive someone else at 5/9 while copying the beacon at 5/2, I tend to think that his 100 Watts to a phased array of 18-element beams might be a little excessive. Of course, at 100 Watts he might even suspect that he may be just a little heavy into the bird. What about the fellow who says with pride, "Oh I'm just using 4 Watts to the antenna". He fails to mention that the antenna just happens to be four 11-element beams in a phased array.

In this day of preamplifiers and widely varying antenna gain systems, the RST report system tends to evaluate receiving systems and not transmitting effectiveness.

Now let's suppose that the convention on satellite signal reporting was changed to reporting "S" units above or below the beacon. The ideal report to aim at would be 5/0. Anyone hearing a "power broker" getting a 5/ +5 would know that he was "hogging" the transponder, and it just might lead him to cut back! (Somehow this

(Continued on page 18)

"Dear Joe:..."

(Continued from page 17)

seems easier and less offensive than just telling him to cut back on his power!). Similarly anyone getting a 5/-3 report (3 "S" units below the beacon) would know that improvements need to be made to their transmitting set up.

I suggest that we dub this the BEACON REFERENCE SIGNAL REPORT SYSTEM and put it into use on the Amateur Satellites. "Relative strength to the transponder beacon" should be truly useful to the station receiving the report and to all that are using the transponder at the time.

Jack, KA5DNP

(An operating suggestion was published in the AMSAT Newsletter many years ago for all satellite operators to adjust their transmitter power so that their received signals were at the same level as the transponder beacon. This sounds like a neat follow up. — Joe)

Macintosh Orbit Prediction Program Available

Dear Joe: Welcome back to the AMSAT editorial folds, its been some time.

I have converted the Satellite Orbit Prediction Program by Tom Clark, W3IWI published in *Orbit Magazine* (No 6, Mar/Apr 1981) to Microsoft BASIC running on an Apple Macintosh computer. If anyone who wants listings would send me an SASE, I will send them copies. If anyone wants a copy of the program, and sends me a formatted 3.5-inch disk and appropriate return postage, I will return it containing both the program and the documentation.

Earl Skelton, N3ES, 6311 29th Pl., N.W., Washington DC. 20015-2221

1989 AMSAT-NA Space Symposium and Annual Meeting

November 10-13, Des Moines, Iowa

By Ralph Wallio, WØRPK *
CITS Chairman AMSAT-89

Central Iowa Technical Society (CITS) planning is well under way for the 1989 AMSAT-NA Space Symposium and Annual Meeting. Hotel, meeting and banquet arrangements are complete. Committees have been formed to support weekend activities.

Hotel accommodations will be at the Des Moines Hampton Inn located just five-minute's drive from Des Moines International Airport. Room rates will be less than $40 per night including courtesy transportation and complementary breakfast. Seminar registration will be available in the hotel's lobby on Friday afternoon and evening.

All seminars, lunch, banquet, annual meeting and Sunday's board-of-directors session will be held at the Meredith Corporation executive meeting complex. Meredith, publisher of numerous magazines and books, i.e., *Better Homes and Gardens,* is donating the use of their facility (free of charge) to AMSAT. Their facility, located less than ten-minute's drive from the Hampton Inn, is equipped for all modes of audio and visual presentations.

Transportation to and from the Hampton Inn, Meredith Corporation and other points of interest will be via chartered buses and the hotel's courtesy van. Rental cars will not be required.

A preliminary schedule for the weekend is as follows:

Friday, 10 Nov 1989

5:00pm-9:00pm
Registration at Hampton Inn

7:00pm-midnight
Informal gathering in a local restaurant

Noon-dawn
Informal meetings in hospitality suite

Saturday, 11 Nov 1989

6:30am-8:30am
Complementary breakfast at Hampton Inn

7:00am-noon
Registration (Meredith)

8:00am-noon
Seminar paper presentations (Meredith)

Noon-1:00pm
Lunch (Meredith)

1:00pm-5:00pm
Seminar paper presentations (Meredith)

5:00pm-7:00pm
Cash bar at Hampton Inn

7:30pm-midnight
Banquet and Annual Meeting (Meredith)

Midnight-dawn
Informal meetings in hospitality suite

Sunday, 12 Nov 1989

6:30am-8:30am
Complementary breakfast at Hampton Inn

8:00am-noon
Seminar paper presentations (Meredith)

1:00pm-midnight
Board-of-directors meeting (Meredith)

Midnight-dawn
Informal meetings in hospitality suite

Monday, 13 Nov 1989

6:30am - 8:30am
Complimentary breakfast at Hampton Inn

8:30am-4:00pm
Board-of-directors meeting.

Availability of an information and registration package will be announced in a forthcoming issue of *The AMSAT Journal.* Formal announcement of the Annual Meeting and a call for registration will be mailed with ballots for elections to the Board of Directors in late summer of 1989.

The Des Moines International Airport is served by America West, American, Braniff, Midway, Northwest, TWA and United Air Lines. Hotel reservations may be made by calling 1-800-HAMPTON and mentioning the RAS GROUP or by calling the Des Moines Hampton Inn directly at 515-287-7300.

Layered Command Team Development

AMSAT-NA is forming a layered satellite monitoring and command team to ensure the continuing availability of interested and trained spacecraft operators. The primary responsibility of team members at all levels will be to monitor spacecraft performance and to collect, analyze, report on, and archive relevant telemetry and tracking data.

Team members will be assigned to one of six participation levels:

Level-0 — Capable of OSCAR operation, application on file.

Level-1 — Demonstrated ability to collect and analyze data from all currently functioning amateur radio satellites.

Level-2 — Sustained, significant contributions to the effort.

In accordance with their own specialties, those able and willing to proceed beyond Level-2 may be recommended to satellite owners for command responsibilities at one of the remaining three levels as openings and needs occur.

Level-3 — Payload operators (PBBS sysops, etc.)

Level-4 — Command stations (perform corrective intervention as needed to ensure and optimize satellite health)

Level-5 — System developers and representatives of satellite owners.

All participants are expected to proceed through the program beginning at Level-0.

(Continued on page 23)

*125 Highway G-24, Indianola, IA 50125.

The Terminology Used in Orbital Predictions

By Joe Kasser G3ZCZ*

Introduction

Most everyone is used to seeing the Keplerian elements and inserting them into computer programs for predicting OSCAR passes, but how many people know what they actually mean? This article discusses the terminology used in describing the orbits of objects in space. Get a pencil and paper and copy the drawings in this article and make new ones as you read.

Basics

As an object moves in space it is subject to gravity. The object itself has mass and attracts other objects and is at the same time attracted by the mass in the other objects. Sir Isaac Newton formulated the law of gravity, which can be described in the following manner.

All bodies attract each other with a force called gravitational attraction. The strength of the mutual attraction between two bodies is dependent on their masses, and the distance between the bodies. In fact the closer together that the two bodies are, the greater is the mutual attraction. Mathematically this can be expressed as the gravitational attraction between two bodies is directly proportional to their masses and is inversely proportional to the square of the distance between them.

Planet Earth is an object moving in space and exerts a gravitational force. It pulls anything close to it towards the center of the Earth at an increasing speed. An increasing speed is known as acceleration. The acceleration due to gravity at the surface of the Earth is given the value of 1 Gravity (G).

Orbital Trajectories

If the Planet pulls everything towards itself, what keeps things in orbit around it? For example, if you throw a rock up into the air, gravity and air resistance (drag) slow it down and it falls back to Earth. If you shoot a bullet towards the horizon it will travel much further than the stone did, but will still fall to Earth (unless it hits something first).

If you launch a rocket towards the horizon, the rocket will accelerate as long as the fuel lasts. When the rocket fuel is exhausted, the rocket will continue to travel in a straight line until other forces alter its path. If the rocket is low enough, the molecules of air or the atmospheric drag tends to slow it down. At any height it will still be pulled back by gravity. The force of gravity always acts towards the center of the Earth. On its own the rocket will travel in a straight line. Gravity acting downwards will curve the path of the rocket around the Earth.

The force of gravity will pull the rocket away from its horizontal path and cause it to fall in a downwards direction. Now the surface of the Earth is also curved and also curves away in a downwards direction. If speed of the rocket is such that the rate of descent (due to the gravitational attraction of the Earth) is equal to the curvature of the Earth, the rocket will always remain at the same height , namely, it will be in a circular orbit. If the rocket does not have enough speed it will gradually fall back to Earth, and if it has more speed, it will tend to rise above the Earth.

If the rocket continues to burn fuel the speed of the rocket increases and the path it takes rises away from the surface of the Earth. When the fuel is exhausted, gravity is still there and still slows down the rocket. As it slows down its path curves more sharply until at its furtherest point (apogee) it is traveling parallel to the surface of the Earth. It is, however, traveling slower than the speed necessary to maintain a circular orbit at that altitude and starts to curve back towards the Earth. The force of gravity now acts in a downward and (slightly) forward direction and speeds up the rocket until at its lowest point (perigee) it once again is traveling parallel to the surface of the Earth but now has enough speed to rise away from the surface. This process repeats each time around and produces an elliptical orbit.(In this orbit, the center of the Earth is one focus of the ellipse.)

To place a satellite into an orbit, it must be given the right amount of speed for the desired orbital altitude so that the orbital velocity at apogee is such that it just balances the gravitational pull of the Earth. Since the force of gravity decreases with altitude, the orbital velocity is also different at different altitudes. Any rocket can lift a small mass to a much higher altitude than it can lift a large mass. How much and how high will depend on the rocket itself.

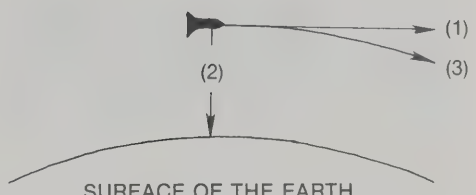
Types of Orbits

Different orbits are used for different purposes. Circular and elliptical orbits come in various forms depending on the angle that the plane of the orbit makes with the equator of the Earth. This angle is known as the angle of inclination of the orbit (with respect to the equator). A polar orbit has an angle of inclination such that the spacecraft in that orbit can see the polar regions of the Earth. A geostationary orbit is one which has an angle of inclination parallel to the equator and an altitude of 22,240 miles (35,790 km) and the spacecraft moves in its orbit at the same speed as a point on the surface of the Earth below it. The spacecraft thus appears to be stationary with respect to the Earth below it.

The direction in which the satellite moves around the Earth determines the type of orbit. One which travels along its orbit in the same direction as the rotation of the Earth (eastwards) is said to be in a direct or prograde orbit. One which travels against the rotation of the Earth (westwards) is said to be in a retrograde orbit.

The movement of an object in space can be described mathematically. In the early 17th century, the only known objects in space were the Sun, the Moon, the Planets, a few comets and the stars. It was then that Johannes Kepler formulated three laws that first described the movement of the Planets about the Sun.

EFFECT OF GRAVITY ON DIRECTION ROCKET TRAVELS



(1) ROCKET WANTS TO TRAVEL IN THIS DIRECTION

(2) GRAVITY PULLS AT ROCKET

(3) ROCKET TAKES THIS PATH

(3A) IF PATH 3 IS PARALLEL TO THE SURFACE OF THE EARTH THE ROCKET IS IN A CIRCULAR ORBIT, IT FALLS AROUND THE EARTH

(3B) IF PATH 3 IS HIGHER THAN 3A, THE ROCKET WILL RISE AWAY FROM THE SURFACE

(3C) IF PATH 3 IS BELOW 3A, THE ROCKET WILL FALL BACK TO EARTH

*Editor, see page 2 for address.

Kepler's Laws

1. Each Planet revolves about the Sun in an orbit that forms a circumference of an ellipse with the Sun at one focus of the ellipse.

2. The line from the center of the Sun to the center of the Planet (called the radius vector) sweeps out equal areas in equal periods of time as the Planet travels along the circumference of the ellipse.

3. The square of the time taken for a Planet to travel around the circumference of the ellipse (period of revolution of the orbit of a Planet) is proportional to the cube of the mean distance of the Planet from the Sun.

In the first law, the focus within the Sun is actually at the center of mass of the Earth-Sun system and not at the center of the Sun.

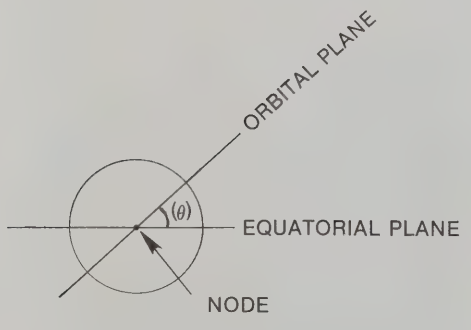
Orbital Elements

The position of an object in space can be expressed in terms of its relationship with other bodies. Each orbit can be described in terms of a number of parameters which supply enough information to accurately locate the satellite. Six basic parameters are used to describe the position of a satellite in an elliptical orbit are described in the following paragraphs. They are Angle of Inclination, Right Ascension of Ascending Node (RAAN), Eccentricity, Semimajor Axis, Argument of Perigee and Epoch time of Ascending Node. Consider each one in turn.

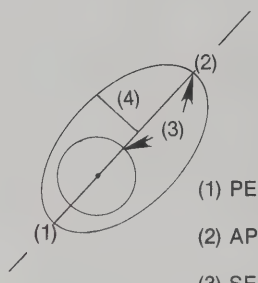
Angle of Inclination.

The angle of inclination of an orbit is the angle between the plane of the orbit and the equator of the Earth. A satellite moving in a direct or prograde orbit has an angle of inclination between 0 and 90 degrees, one moving in a retrograde orbit has an angle of inclination of between 90 and 180 degrees.

The maximum northern and southern latitudes reached by a satellite are equal to the angle of inclination of its orbit.



(θ) ANGLE OF INCLINATION



(1) PERIGEE

(2) APOGEE

(3) SEMI MAJOR AXIS

(4) SEMI MINOR AXIS

Right Ascension of Ascending Node (RAAN).

While the spacecraft is moving around the Earth, the Earth is at the same time rotating on its own axis, and is itself traveling in an orbit about the Sun. The Right Ascension of Node is needed as a fixed reference point in the sky.

Astronomers use the term celestial sphere to describe the sky for two reasons. First, from where we are standing on the surface of the Earth, the sky seems to be painted on the inside surface of a sphere (with the stars in fixed positions on the sphere). Second, have you ever known scientists to use a short commonly used word when they can use long ones?

The orbital plane of a spacecraft intersects the equatorial plane of the Earth in two places (one on each side of the globe). A line drawn between these two points and continued out to the celestial sphere is called the line of nodes. The two points on the line of nodes where the planes intersect are called the point of nodes. Most globes (and maps) show the north pole upwards. When the spacecraft crosses the equatorial plane (passes above the equator) going northward it is ascending from south to north and that node point is known as the ascending node. Conversely when the satellite continues on its way and travels half way around the world it crosses the other node on the equatorial plane descending to the southern hemisphere. This second node is called the descending node.

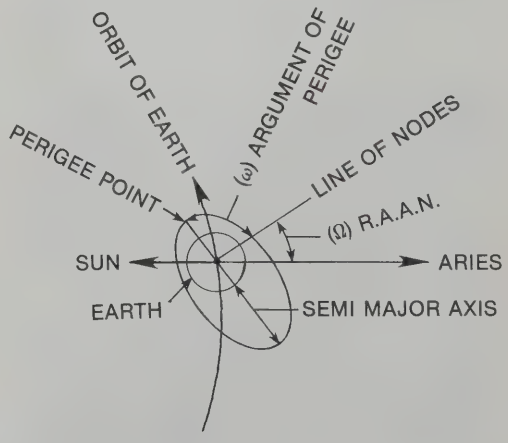
The Earth is in an inclined orbit around the Sun, just like a satellite is in orbit around the Earth. The Earth has an ascending and descending node around the Sun, in a similar manner to a spacecraft in orbit around the Earth. The orbital plane of the Earth is known as the Ecliptic. The direction in space from the center of the Earth through the intersection of the ecliptic and the Earth's equatorial plane out to the celestial sphere is called the Vernal Equinox or the First Point of Aries because it points to the constellation of Aries (which is so far away that, for all practical purposes, it is in a fixed direction).

The angle between the line of nodes for the ascending node of the orbit of the spacecraft continued out to the celestial sphere and the vernal equinox when measured in an easterly (right as opposed to westerly/left) direction along the earth's equator is defined as the Right Ascension of the Ascending Node (RAAN).

Eccentricity and Semimajor Axis

In a circle, the radius of the circumference is constant. This means that an object traveling along the circumference is always at a constant distance from the center or focus of the circle. The general shape of an orbit is an ellipse. Unlike a circle, an ellipse has two focal points. The distance between each of the focal points of the ellipse and an object on the circumference is constant. A line through the two focal points and the circumference is called the Semimajor Axis. The longest line perpendicular (at 90 degrees to) the semimajor axis passing through the circumference of the ellipse is called the Semiminor Axis.

The mathematical term describing the overall shape of an ellipse is called Eccentricity. When the eccentricity of an ellipse is 0 the length of the semimajor axis is equal to the length of the semiminor axis and the shape being described is a circle. A value of eccentricity greater than 0 means that there is a difference between the lengths of the axes and the shape of the ellipse flattens out. Eccentricity describes the shape of the orbit and the length of the semimajor axis describes the size of the orbit. If these two parameters are known, the apogee and perigee values for the orbit can be calculated.



Decay Rate

The Earth has an atmosphere. It is dense at ground level and thins out with altitude. The Earth's gravity attracts the molecules of gas in the atmosphere and stops them from escaping. As the satellite travels along its elliptical orbit around the Earth, its altitude changes. When it is close to perigee, it bumps into molecules of air and is slowed a minute amount. The lower it gets the greater the drag on it by the air. Each time it goes through the ascending node it will be going imperceptibly slower. The rate of change of speed through the atmosphere at the perigee pass will depend on the type of orbit and on the altitude of the perigee point. In general, satellites with low perigee points will be slowed faster than satellites with higher perigee points. The effect of this slowing down at the perigee over the long term is to lower the apogee point because the satellite no longer has the velocity to reach the previous apogee. Over the long term, the satellite tends to spend more time in the denser parts of the atmosphere which then tends to circularize the orbit (at the perigee) at which point the air drag acts continuously on the spacecraft and the orbit disintegrates. The rate of change of the orbit measured at a particular epoch is called the decay rate.

Argument of Perigee.

A line drawn between the perigee of an elliptical orbit and the center of the Earth is called the line of perigee. This line also passes through the apogee and is the semimajor axis of the orbit. The angle between the line of perigee and the line of nodes is called the argument of perigee. It is a measurement of the angular distance between them and is measured in the ascending direction from the line of nodes. The argument of perigee thus establishes the position of the ellipse itself within the orbital plane.

Epoch Time (of Ascending Node) and Revolution Number.

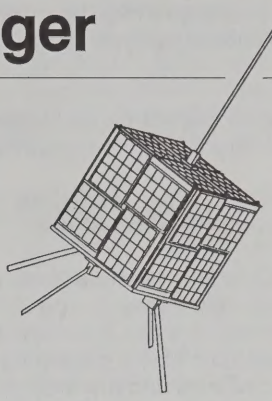
The Epoch time is a time when the satellite crosses its ascending node. This time is given as a Julian date, and is the reference time for when the orbital elements are valid. The Epoch Revolution or orbit number is the orbit number (since first ascending node) for which the element set is valid.

The Mean Motion.

The mean motion of a satellite is a measurement of the number of orbits completed in a day. It is equal to twice the value of PI divided by the time that the spacecraft takes to complete one revolution of its orbit (orbital period).

(Continued on page 23)

DOVE: A MicroSat Classroom Worldwide Messenger



By Richard Ensign, N8IWJ *

DOVE is an acronym for Digital Orbiting Voice Encoder. The satellite carrying the DOVE is to be launched as one of six secondary payloads on the SPOT-2 mission in the Fall of 1989 and will transmit signals that will be receivable in most countries. The DOVE project is sponsored by the Brazilian Radio Amateur Satellite Organization, BRAMSAT. Dr. Junior Torres de Castro, PY2BJO, President of BRAMSAT, heads the DOVE project. As it circles the world, the satellite will transmit digitized voice messages along with spacecraft information. DOVE's educational focus will allow it to be used in ways that cut across subject matter boundaries. Physics, astronomy, electronics, geography, and language arts classrooms can all make creative use of the signals from DOVE. The satellite can also be used at many educational levels from early elementary school through high school. For example, a kindergarten teacher in New Zealand, now studying for her Amateur Radio license, plans to use DOVE in a tape assisted reading program.

DOVE's internal computer keeps watch over the condition of satellite. It can inform students and teachers as to how it is functioning. DOVE will tell us its temperature, electrical condition, whether it's in sunlight or darkness and even its spin rate. This information, called telemetry, can prove very useful in giving students some idea as to the conditions under which an orbiting spacecraft operates. Telemetry will be read out in English and will alternate with other DOVE activities. DOVE will transmit on a frequency of 145.970 MHz with a power of up to four watts. DOVE's downlink signal will be easily picked up on the ground by simple scanner/receivers with whip antennas or by Amateur Radio equipment. Most schools will be able to clearly receive the signal right in the classroom. Satellite passes will occur during the school day at about 10:30 a.m. and again in the evening at about 10:30 p.m. local time.

Once DOVE is launched and activated, a Project DOVE Teacher's Guide, now in production, will be made available to schools wishing to integrate this unique teaching tool in orbit into the science, social studies and language arts areas of the curriculum.

DOVE Language Arts Project 1 (LAP 1)

Following launch, DOVE will begin a special Amateur Radio educational project to last for approximately its first year in orbit. Short messages expressing student's wishes for peace in the world are being created in the classroom and submitted by their schools world-wide. Tapes of the youth reading their own messages will be digitized and uplinked to the satellites computer memory. The student's own voice will then be transmitted to Earth by DOVE.

Elementary or secondary school principals that wish their school to participate in LAP 1 should inform their teachers of the project and form a message selection committee. Classes involved in creating messages for DOVE should preface their writing with a discussion exploring the meaning of peace in the world and at home. This should include a look at the world's geography and some of the areas where major conflicts have taken place or are now taking place. Special emphasis might be placed on how conflict disrupts families and children. Of course, the "world shrinking" friendships created through the Amateur Radio hobby should also be examined.

How to Tape Messages for DOVE.

Place all your messages on one new standard audio cassette tape. Use the best recorder you have available in your school (avoid recorders with built in microphones) and record the student's voices at moderate volume with the microphone about 25 cm away from their mouths. This should produce a clear undistorted recording. Make the recording in a quiet area and avoid rustling paper or background noises during the reading. Advise the students to speak slowly and distinctly (they will tend to rush). Avoid overdramatics. About 15 seconds of silence should precede each message and follow it before the next message. Begin each message with the youth saying (in his own language).....

MY NAME IS (name). I'M (age) YEARS OLD AND I LIVE IN (city, state/province/territory) IN THE COUNTRY OF (country).

*Address given in article.

LAP 1 Message Criteria

1. LAP 1 messages may be created by students within the age range 8 to 18 years.

2. Messages should be no longer than 40 words. There is no minimum length.

3. Students may write as many messages as they would like.

4. Since DOVE's transmissions are on frequencies allocated to the Amateur Radio service, there is a particular concern on the part of the governing agencies both national and international that transmissions not be used for propaganda purposes. Please be sensitive to these concerns in selecting LAP messages. The following comments should be helpful. Feel free to call us if you have concerns.

a. Messages with more than one interpretation should be avoided, i.e., "Fight for peace!"

b. Messages should be global in nature and not focus on local or regional peace issues or areas of conflict.

c. Names of countries or regions should not be mentioned or specific countries inferred.

d. The best messages will have a youth's perspective or a globe-circling satellite perspective of the world.

e. Since many of the world's conflicts past and present are based on issues of a religious nature, messages which speak of a deity should do so in broad terms.

f. The word "nuclear" should be avoided as should "World War III" or "Star Wars" because of negative cultural attitudes in specific countries connected with these terms.

The school selection committee should pick the top 10 messages based on the above criteria. The youth's name and age should be included with the message and an English translation should be provided if the message is not in English. All messages selected should be typed with English translations immediately following if applicable.

We suggest you get all the students together and tape in one session. Clearly label your tape with the school's name and address and the date. Send the audio tape, typed messages and translations, and a cover letter on school stationery to the message collection center. Package the tape carefully to avoid damage in transit. Send to:

PROJECT DOVE
c/o Richard C. Ensign
AMSAT Science Education Advisor
421 N. Military
Dearborn, MI 48124 U.S.A.
Phone: 1-313-274-1718 (home)
1-313-278-0900 (school)

AMSAT/BRAMSAT personnel reserve the right to screen and further select the messages. However, careful local screening and good recordings should not make this necessary. Unless further selection is done, a school may expect that all messages they choose and send will be transmitted by DOVE. A confirmation of receipt and acceptance will be sent to each school participating. Each youth who writes a message that is spoken by DOVE in orbit will receive a special certificate from BRAMSAT and information on how they can become Radio Amateurs. There is no deadline for submission of messages.

It will not be possible to notify a school as to when its student's messages will be spoken by DOVE. Long-term student listeners receive a global concept of student's views of peace and, when their message comes along, it is seen as a part of this perspective and not as a special project undertaken by one school in isolation. This will also emphasize the global nature of the Amateur Radio hobby. Messages not in English will be followed by an English translation as this is the accepted international language of Amateur Radio.

DOVE is designed for six or more years of active life in orbit, During that time its telemetry and voice synthesizer will be used to support many Amateur Radio educational projects. Students and teachers are invited to exercise their creativity in suggesting different ways that DOVE can be used in the classroom.

The DOVE Teacher's Guide is being designed for use by educators with the assistance of local Amateur Radio operators. Teachers of children from kindergarten age through high school will find the guide useful in making the DOVE MicroSat a part of their curriculum. A half scale paper model of DOVE will be included in the Guide for teachers to hang in the classroom. Refrigerator stick-on-magnets added to the model will allow it to be used in orientation/stabilization demonstrations.

Sample LAP 1 DOVE Messages

The messages shown here were written by the Crestwood High School Creative Writing Class, Dearborn Heights, Michigan, U.S.A.

The stars shine above us as we gaze with awe. We all have one hope and prayer...world peace. — Jill Totsky, Age 17

If we disarm the weapons of the world, our future will flourish. Trees and flowers will bloom forever. The clouds of war will never block out the light of life. — Jennifer McCloskey, Age 17

World peace means coming together for the good of the Earth. We must love each other for what we are. If war is nonexistent, everyone will be safe. — Nicole Witt, Age 17

Peace shall come about by a oneness of understanding. We need to listen and understand one another, to love and be loved. — Carol Swistock, Age 17

The eyes of a child, so playful and careful. When war begins a tear slides down his cheek. Give children, the future of the world, a chance. — Kelly Murphy, Age 16

As I circle the world I see all nations. May each get to know the other and grow together in peace and harmony. — Sample written by instructor

Children are so young and know so little of the real world. Will the arguing nations ever stop? Let's not shatter the children's dreams. — Stephanie Churchvara, Age 17

No one heart can be big enough to hold peace. But if our hearts come together, peace will be spread throughout the world. — Angie Tomlinson, Age 16

No more war. No more hate. Peace and love. Wouldn't life be great. — Kelly Murphy, Age 16

SOFTWARE FROM AMSAT

To order, send check or money order to AMSAT Software, Post Office Box 27, Washington DC, 20044.

1. ORBITS II — For IBM PC and compatibles, 256k RAM memory, IBM Color Graphics Adapter (CGA) and compatible monitor, one 5-1/4 inch floppy diskette drive and DOS 2.0 or later. $35 members; $45 non-members.

2. ORBITS III — Functionally equivalent to ORBITS II but has been designed for use with the IBM Enhanced Graphics Adapter (EGA) and Enhanced Color Display. $45 members; $55 non-members.

3. N4HY QUIKTRAK 3.2 — For IBM PC, DOS 3.0 or later. No 8087 math coprocessors needed but will run much faster with it. 256K bytes of RAM. CGA color graphics is only needed for the map display routine. $70 members; $90 non-members.

4. QUIKTRAK FOR IBM — For those IBM owners that do not have graphics capabilities (See Apple QUIKTRAK). $25 members; $35 non-members.

5. C-64 SUPERTRAC — This is a com-

bination of N4HY's Quiktrak program and enhanced graphics. This program provides sharp, clear and colorful graphics with excellent scheduling flexibility. This program also has the ability to drive commercially available dual axis rotors. Disk only. $30 members; $40 non-members.

6. APPLE QUIKTRAK — Menu driven program for tracking and scheduling of amateur satellites. Incorporates a very fast algorithm for finding usable passes of the satellite of your choice. Satellite pointing angles relative to your QTH and a "window track" mode are included. The "window track" feature identifies mutual "windows" between your QTH and other specified locations around the world. Includes menu driven utilities for data entry. Requires an 80 column card and 64K. $25 members; $35 non-members.

7. MACTRAK — Written by W7HR provides tabular data output of tracking and scheduling information for up to 10 satellites. Graphic displays include rectangular, polar and great circle world maps, and there is a VIEW mode which shows earth as seen from the satellite at any time. A real-time mode will show data as it changes and is compatible with the KLM/Mirage antenna tracking interface. Data can be displayed on the screen or output to the Imagewriter printer. A propagation prediction package is also included which will calculate the maximum usable frequency (MUF) to any point, sunrise & sunset times, bearings & distances, and display the gray-line. MacTrak requires a 512K or larger MacIntosh with a double sided (800K) disk drive, and an Imagewriter printer. $40 members; $50 non-members.

8. C-128 — This is the ORBITS program that is specifically written to take advantage of the unique capabilities of the C-128. ORBITS uses time-based incrementing with user-selected increments of time. This results in uniform time increments between data lines. The ORBITS Program features automatic page formatting and pagination. As many as twenty satellites may be entered into Keplerian files. It requires an 80 column monitor and a Commodore compatible printer. $30 members; $40 non- members.

9. COMMODORE AMIGA — Designed for the AMIGA operating in 80 column mode. Requires a minimum of 256K RAM. Translated to AmigaBasic. Runs under Workbench V1.1 or V1.2. Has the same features as the C-128 ORBITS but runs considerably faster. Has provision for mode and phase programming to alert you as to which transponder is active. 3-1/2 inch disk. 30 members; 40 non- members.

10. QUIKTRAK for TRS-80 Model 4/TRSDOS 6.0 — This is the N4HY QUIKTRAK program modified to run on the Model 4. $30 members; $40 non-members.

The W3IWI Tracking Program is available for the following computers. Each program provides all the data needed for tracking satellites, space shuttles, etc. in an easily understandable tabular form. All are $25 for members; $35 for non-members.

11. TRS-80 COLOR COMPUTER — 32 K, extended BASIC, cassette only.

12. TRS-80 Model 3 — 32K, one disk drive.

13. TEXAS INSTRUMENTS TI99/4A — cassette only.

14. ATARI 400 & 800 — disk only.

15. HP-41 PROGRAMMABLE CALCULATOR - ORBIT 1 — This program will output AZ and EL in real-time or all W3IWI parameters in the prediction mode. Special requirements: HP-41C + QUAD Memory, HP-41CV, HP-41CX, Card Reader (desirable but not essential). ORBIT II - the same as ORBIT 1 with the addition of functions from the Time Module for output of time and input from the time clock in a real-time mode. Please specify ORBIT I or ORBIT II.

16. UOSAT-OSCAR 9/OSCAR 11 DATA CAPTURE, EDITING AND TELEMETRY DECODING PROGRAM FOR IBM-PC — A brilliant piece of work by Bob Diersing and his co-author Aaron Brown. One program does the data collection and another does the tedious chore of automatically editing the data for clean frames. Includes an outstanding manual to accompany these programs. $35 for members; $45 for non-members.

ORBITS II & III Compiled programs providing the following features:

(1) Real-Time satellite tracking in either a tabulated mode or in a graphics presentation of a world map upon which the satellites are moved. Up to eight satellites can be tracked simultaneously in this mode. The map is displayed in a single color in ORBITS II or in multiple colors in ORBITS III. A single satellite can be selected and an acquisition circle will be drawn around that satellite showing its coverage. All eight satellites will continue to be moved in this mode.

2) Automatic control of azimuth and elevation rotors when using the Kansas City Tracker computer interface or equivalent.

3) Batch output for a single satellite for selected periods and update intervals. Can be output to screen, printer or disk file.

4) Keplerian elements can be entered into three files with up to eight satellites in each file.

5) Ground station data is entered by following program prompts at setup time. The map can be centered on the screen at any longitude.

6) Extensive prompting is used with error routines to protect against invalid input. Operating instructions are contained in a file which can be printed by the user.

N4HY QUIKTRAK 3.2 — This program is a many featured satellite tracking and usage planning package.

1) It supports many antenna rotator packages

2) It has a standard interface for control of radios through the serial interface for ICOM, Kenwood, YAESU and others

3) It will gather telemetry using interrupt driven serial port device drivers written for the CBBS and WA7MBL Packet BBS system

4) Has graphics display routine which shows one satellite and the sunline and range circle, and time to AOS or LOS. We also have a graphics mode that displays all satellites in the Keplerian file on the map

5) It tracks one satellite for many cities

6) It tracks all the satellites for your QTH and gives AOS, LOS information for all of them

7) Has a dumb terminal emulator

8) Displays Equator crossing or apogee times and locations.

Command Team Development

(Continued from page 18)

Some may be accelerated based on demonstration of past activities of comparable scope and magnitude. Appropriate awards, certificates, endorsements, and other incentives will encourage progress.

For further information and a Level-0 application, contact Ralph Wallio, 125 Highway G-24, Indianola, Iowa 50125.

Terminology

(Continued from page 21)

The Catalog Number

The catalog number is the number given to the object.

Mean Anomaly

As the satellite travels along its orbit, its position changes. The angle (measured in the direction of forward rotation) between the position of the spacecraft and the line of perigee is called the true anomaly. The speed of the spacecraft is different at different parts of the orbit. Calculations are simpler if the speed is considered to be constant. The constant value is the average speed of the spacecraft in its orbit. The mean anomaly is the hypothetical position of the satellite in its orbit (along the ellipse) if it is assumed to be traveling at its average speed.

Conclusion

This article should have increased your understanding of the terms used to define the orbit of an object moving around the Earth.

AMSAT Orbital Elements from WØRPK, April 15, 1989.

Satellite:	UO-9	AO-10	UO-11	FO-12	AO-13	RS-10/11
Catalog number:	12888	14129	14781	16909	19216	18129
Epoch time (89):	098.60213918	098.17631485	095.57002775	083.69611252	089.37166448	100.86343442
Element set:	509	393	430	137	34	723
Inclination:	97.5648	26.4531	98.0078	50.0189	57.2895	82.9225
RA of node:	148.1913	271.3989	156.4687	198.0467	213.9669	287.8876
Eccentricity:	0.0003572	0.6054626	0.0012594	0.0011097	0.6688587	0.0010641
Arg of perigee:	67.2249	31.9599	184.7624	130.5680	201.4192	235.0151
Mean anomaly:	292.9463	353.4785	175.3464	229.6122	106.6281	125.0041
Mean motion:	15.50735176	2.05880931	14.63297605	12.44398749	2.09699506	13.71963799
Decay rate:	6.4017e-04	2e-08	2.447e-05	-2.5e-07	-2.8e-07	4.17e-06
Epoch rev:	41817	4377	27192	11888	608	9016

Satellite:	MET-2/16	MET-2/17	MET-2/18	MET-2/2	NOAA-9	NOAA-10
Catalog number:	18312	18820	19851	19336	15427	16969
Epoch time (89):	102.38130210	102.97162720	103.04827285	102.42315186	096.42363485	098.89382834
Element set:	258	100	22	172	355	214
Inclination:	82.5530	82.5460	82.5242	82.5498	99.1388	98.6423
RA of node:	271.6742	332.3925	211.0981	222.1996	81.9811	130.6919
Eccentricity:	0.0013383	0.0018138	0.0015949	0.0017804	0.0015803	0.0014857
Arg of perigee:	27.2982	91.6737	128.0660	350.8080	151.2156	92.0456
Mean anomaly:	332.8879	268.6501	232.1947	10.2434	208.9890	268.2411
Mean motion:	13.83451581	13.84143245	13.83777833	13.19497204	14.11939156	14.22930050
Decay rate:	2.19e-06	2.86e-06	1.17e-06	4.06e-06	8.36e-06	9.36e-06
Epoch rev:	8341	6066	607	3425	22232	13408

Satellite:	NOAA-11	MIR	SALYUT-7	AJISAI
Catalog number:	19531	16609	13138	16908
Epoch time (89):	097.14900325	102.92687494	102.94303824	066.68751816
Element set:	66	783	516	119
Inclination:	98.9332	51.6244	51.6104	50.0132
RA of node:	41.5246	329.5228	276.5105	250.1037
Eccentricity:	0.0013472	0.0012793	0.0001414	0.0011436
Arg of perigee:	73.1405	182.8931	180.1825	89.1702
Mean anomaly:	287.1242	177.2200	179.9264	271.0451
Mean motion:	14.10925555	15.62480343	15.39733803	12.44376385
Decay rate:	8.10e-06	5.9506e-04	5.9823e-04	-1.8e-07
Epoch rev:	2745	18101	39813	11677

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